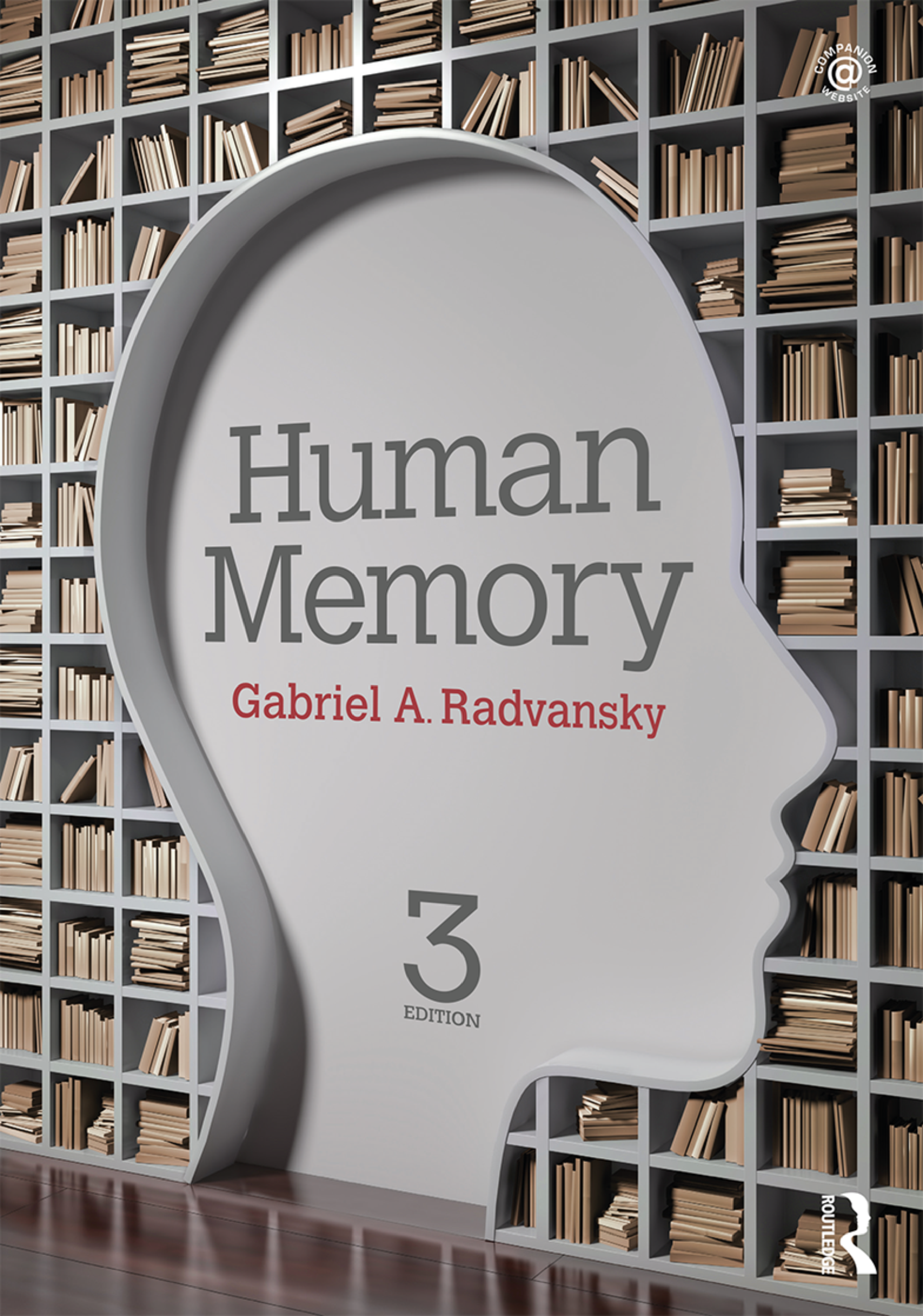

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Human Memory
Gabriel A. Radvansky
3
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Human Memory

This book provides a complete survey of research and theory on human memory in three major sections. A background section covers issues of the history of mem ory, and basic neuroscience and methodology. A core topics section discusses sensory registers, mechanisms of forgetting, and short-term/working, nondeclarative, episodic, and semantic memory. Finally, a special topics section includes formal models of memory, memory for space and time, autobiographical memory, memory and reality, and more. Throughout, the author weaves applications from psychology, medicine, law, and education to show the usefulness of the concepts in everyday life and multiple career paths. Opportunities for students to explore the assessment of memory in laboratory-based settings are also provided. Chapters can be covered in any order, providing instructors with the utmost flexibility in course assignments, and each one includes an overview, key terms, *Stop and Review* synopses, *Try It Out* exercises, *Improving Your Memory and Study in Depth* boxes, study questions, and *Putting It All Together* and *Explore More* sections.

This text is intended for undergraduate or graduate courses in human memory, human learning and memory, neuropsychology of memory, and seminars on topics in human memory. It can also be used for more general cognitive psychology and cognitive science courses.

New to this edition:

- Now in full color.
- More tables, graphs, and photos to help students visualize concepts.
- *Improving Your Memory* boxes highlight the practical aspects of memory, and *Study in Depth* boxes review the steps of how results were constructed.
- The latest memory research on the testing effect, the influences of sleep, memory reconsolidation, childhood memory, the default mode network, neurogenesis, and more.
- Greater coverage of neuroscience, fMRIs, and other recent advances such as NIRS and pupilometry.
- A website at www.routledge.com/cw/radvansky with outlines, review

points, chapter summaries, key terms with definitions, quizzes, and links to related websites, videos, and suggested readings for students as well as PowerPoints, multiple-choice and essay questions, discussion questions, and a conversion guide for current adopters for instructors.

Gabriel A. Radvansky is Professor of Psychology at the University of Notre Dame.

Human Memory

Third Edition

Gabriel A. Radvansky

Routledge
Taylor & Francis Group
NEW YORK AND LONDON

Third edition published 2017
by Routledge
711 Third Avenue, New York, NY 10017

and by Routledge
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

Routledge is an imprint of the Taylor & Francis Group, an informa business

First edition published by Allyn & Bacon 2005
Second edition published by Routledge 2010

Library of Congress Cataloging in Publication Data
A catalog record for this book has been requested

ISBN: 978-1-138-66540-8 (hbk)
ISBN: 978-1-138-66541-5 (pbk)
ISBN: 978-1-315-54276-8 (ebk)

Typeset in Stone Serif
by Florence Production Ltd, Stoodleigh, Devon, UK

Visit the companion website: www.routledge.com/cw/radvansky

For Amy

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PREFACE

This book is a student's guide to human memory, the properties of memory, theories about how memory works, and how an understanding of memory can give us a better idea of who we are and why we do what we do. Although I have tried to provide a reasonably comprehensive survey of many issues of the modern study of human memory, my main concern is the audience. Most college classes on human memory consist largely of psychology majors who are planning to go on to some field of psychology other than memory research, such as clinical or social psychology. Many others plan to go on to nonpsychology fields, such as medical or law school. Other students are not psychology majors but are taking the class because they think human memory would be something interesting to learn about (and they are right). Only a small minority of students will plan to do research on memory. As such, I have tried to write this book with the goals, interests, and backgrounds of the majority of the students in mind, while still providing enough information and detail to satisfy the "memory" student. I have taken a number of steps along these lines.

First, in addition to foundational topics that are necessary for a basic understanding of how memory works, I have tried to focus on topics that will be helpful and useful whatever the student's ultimate goal. I have tried to avoid going into detail about the minutiae of various topics and have instead focused on the big picture. However, there may be cases where I do present a number of different experimental outcomes or theoretical positions. I have done this to provide the student with a sense of the difficulty and complexity of studying human memory, and the degree of careful and rigorous thinking and action that are needed to get at the truth of the human condition.

I mention several times that a particular study was conducted using students from this college or that university so that readers can associate with the information presented in this book. The participants in these studies are the same sort of people sitting in your classroom. I have tried to avoid language that would alienate a student, which can put up a barrier between the student and the material.

I have also tried to present the materials about memory from a number of different perspectives. Some of these come from experimental research on memory itself, such as perspectives from behavioral data, neurological data, and computational modeling. In addition, I present details about how various topics relate to work outside the realm of memory research, such as work in social, clinical, or developmental psychology, or even fields as far-flung as law enforcement.

A quick survey of this book will reveal that it has a lot of chapters. Perhaps too many for a single class term. That's O.K. That was the intention. The field of memory is broad, and different classes place different emphases on different topics. I would expect that most classes would be assigned and use Chapters 1–9 of this book. This is the background and core knowledge that one needs to understand human memory. Then, I would expect that the instructor would select those choices from Chapters 10–18 that best suit their class and its goals. Of course, if you want to assign all 18 chapters, go for it!

I have also sprinkled throughout the book a number of boxes to highlight different things. These boxes serve to accomplish three goals. First, some of these are Try It Out boxes, which provide descriptions of how to do studies that can illustrate salient findings in memory research. These are helpful for any students who might have a lab section associated with their course. Even if not, they give the student a better idea of how to set up and test memory, and the scientific enterprise more generally. Second, some of these are Study in Depth boxes, which show detailed accounts of actual studies in memory research, how they were set up, who was involved, the methods that were used, and the results that were found. These provide an opportunity for students to better grasp the scientific method as it is applied to the study of memory. This includes the identification of a problem, the derivation of the materials and the experimental design, the manipulation of various independent variables, the use of an appropriate dependent variable, the data collected, and how it was interpreted. Finally, some of these are Improving Your Memory boxes, which illustrate, in a more direct way, how the basic findings and principles of research psychology can be extended to real life. Research studies in human memory can often seem artificial and so strongly laboratory-bound that it is hard for people who are not experts in the area to see what the value of this work may be to the bigger picture and their own lives. I hope that these boxes go some way to achieving this aim.

Finally, I would like to thank the various people who have helped me along with the development of this book. These include Amy Radvansky for reading through every single chapter to make sure that what I wrote actually makes sense, Kyle Pettijohn for his work on the effective presentation of this material, Jerry Fisher for spotting more typos than I would care to admit, all of my graduate students over the years, all of my students in my learning and memory classes at Our Lady's university, and, finally, all of the assistance from people at Taylor and Francis, including my editor, Paul Dukes, as well as Rachel Severinovsky, Debra Riegert, Jan Baiton, Tamsyn Hopkins, Hugh Jackson, Susan Leaper, Richard Sanders and Abigail Stanley who worked so hard to make this book a reality. So, thanks!

ABOUT THE AUTHOR

Prof. Radvansky received his BA from Cleveland State University under the supervision of Mark Ashcraft and Ben Wallace, and his MA and PhD from Michigan State University in 1992 under the supervision of Rose T. Zacks. He has been a faculty member in the Department of Psychology at the University of Notre Dame since 1993. He is an expert in human memory with over 80 publications. He has served as associate editor for the journals *Memory & Cognition*, the *Quarterly Journal of Experimental Psychology*, *Collabra*, and *Frontiers in Psychology*.

PART 1

Background

CHAPTER 1

Overview and History of Memory Research

Memory is perhaps the most central aspect of human thought. Any question about human nature requires an understanding of memory. Memory makes us who we are, and it is one of the most intimate parts of ourselves. This may be why when we get close to someone there is a sharing of memories. Some people feel that the study of human memory is the closest one can get to a systematic study of the human soul. The aim of this book is to provide you with a survey and guide to what is known about human memory. As with most courses, there are a number of facts and ideas to learn. However, as any good instructor will tell you, the slow accumulation of facts is not the main point of course work. The primary aim is to provide you with a deeper understanding and appreciation of some aspect of the world—and, hopefully, yourself.

A SMATTERING OF DEFINITIONS

Before diving into the subject matter, we need to define how the terms *memory* and *learning* are used. Although it would seem to be a straightforward task, precise, satisfactory definitions can be somewhat elusive. The primary subject of this book is, of course, memory. So what is memory? Well, the problem, and the beauty, of this term is that it has many meanings.

Memory

The word **memory** has three primary definitions (Spear & Riccio, 1994). First, memory is the location where information is kept, as in a storehouse or memory store. Second, memory can refer to the thing that holds the contents of experience, as in a memory trace or **engram**. In this sense, each memory is a different mental representation. Finally, memory is the mental processes used to acquire (learn), store, or retrieve (remember) information. Memory processes are acts of using information in specific ways to make the information available later or to bring that information back into the current stream of processing, the flow of one's thoughts.

Learning

The term **learning** refers to any change in the potential of people to alter their behavior as a consequence of the experience of regularities in the environment. Obviously, learning and memory are closely related. For something to be remembered, it must first be learned. Because of historical circumstances, these terms have become somewhat disconnected in the language of psychology. "Learning" has come to refer more to the acquisition of associations in the context of studies of conditioning often done using animals, such as a rat learning a maze. In this book I use learning in the way it is conventionally used by people in the world, although I may occasionally use it in the more restricted sense.

METAPHORS FOR MEMORY

The human mind is the part of ourselves of which we have the most intimate awareness. Our experiences are our thoughts. That said, most of its workings are not open to direct inspection. You can't see "thinking." Moreover, every experience that the mind has changes it in some way. By reading this sentence, you are changed. These issues lead to a number of problems in trying to understand memory. One has to be clever and develop ways to study memory (see Chapter 3). More relevant here is that there is no simple and direct way to talk about memory. Because of this, people often talk about it in indirect ways, using **metaphors**.

Roediger (1980) has compiled a list of metaphors of memory that have been used over the centuries (see Table 1.1). Some of these metaphors express the idea that memory is a recorder of experience, such as a wax tablet, a record player, a writing pad, a tape recorder, or a video camera. Others imply that different types of memories, knowledge, and times in our lives are stored in different places. These include such metaphors as memory being like a house, a library, or a dictionary. In contrast, another concept is that memories can also be intertwined and interconnected, like a switchboard or network.

TABLE 1.1 *Various Metaphors for Memory*

Metaphor	Examples
Recorder of experience	Wax tablet, record player, writing pad, tape recorder, video camera
Storage locations	House, library, dictionary
Interconnections	Switchboard, network
Jumbled storage	Bird in an aviary, pocketbook, junk drawer, garbage can
Temporal availability	Conveyor belt
Content addressability	Lock and key, tuning fork
Forgetting of details	Leaky bucket, cow's stomach, acid bath
Reconstruction	Building an entire dinosaur skeleton from fossils
Active processing	Workbench, computer program

Source: adapted from Roediger (1980)

Memory is not passive. Some metaphors capture its dynamic characteristics. For example, the process of retrieving one from the chaotic jumble we have accumulated has led to the idea that searching for memories is like trying to catch birds in an aviary or looking for something in a junk drawer, or even a garbage can. This also goes along with the idea that memories are harder to get at over time, as if they were being led away on a conveyor belt. Often a search is required to find memories that meet a current need, like a lock and key, or a tuning fork resonating with a note. Memory retrieval is further complicated by the fact that much of what is stored is forgotten, leaving only a portion of the original, like water in a leaky bucket, or the degrading effects of a cow's stomach or an acid bath. This loss of knowledge requires people to re-create the missing pieces of a memory, using a constructive process, perhaps like reconstructing a dinosaur from the fragments of bones left behind. Finally, there is the active manipulation of information, as if memory were a workbench or a computer program.

The large number of metaphors should give you the idea that memory is a complex thing. Because of its ephemeral nature, we use our knowledge of more concrete and better understood concepts to help us make sense of it. The most dominant metaphor for memory is the literacy metaphor (Danziger, 2008). The advent of written language led people to view memories as things that are written down and put somewhere. This leads to the near universal conception of memory involving encoding, storage, and retrieval, much like writing books and storing them on a shelf. This metaphor treats memories as discrete units, like books or pages, which may or may not correspond to how the brain parses our experiences. The dominant modern version of this is the computer metaphor, which drove the cognitive revolution of the mid-twentieth century.

PHOTO 1.1 *According to one metaphor, memory is like a leaky bucket, being able to hold things for a period of time but constantly losing information*

Source: ConstantinosZ/iStock/Thinkstock

Before moving on, let's look at one more metaphor that is very inaccurate: the idea that memory is a muscle. That is, the more you use your memory, the better it will be. In other words, simply memorizing things will make memory better. There is no evidence to support this. Instead, it is not how much you use your memory but how much information you have in it that is important. Memory is not like a muscle, but more like a key collection. The more keys you have, the more locks you can open.

Stop and Review

The terms *memory* and *learning* are used in specific ways in psychology. In general, *memory* refers to the storage and retrieval of information, and research is more likely to involve humans. *Learning* has a greater association with studies of conditioning that are more likely to involve animals. Memory is not open to direct inspection, so we need metaphors to try to apprehend it. Each metaphor carries a degree of imprecision, but also captures some important characteristic. Various metaphors capture the idea that memory is a recorder of experience, is organized and interconnected, is jumbled and requires a search (better if you have the appropriate keys to unlock them), and actively operates on information. The most dominant metaphors are the computer and literacy metaphors, which treat memories like files on a computer or as if they were stored on shelves, like books in a library.

HISTORY OF MEMORY RESEARCH

Questions about the nature of memory extend back millennia. However, a true systematic, quantified, and rigorous assessment of the nature and limits of human memory did not begin until the end of the nineteenth century. In this section, we review some of the major players in the history of memory research, starting from the ancients.

Ancient and Pre-Modern Thinkers

Our understanding of memory has developed over time and has been influenced by people ranging from the great philosophers of ancient Greece to those from modern times. One of the first philosophers to record his thoughts on memory was Plato (ca. 428–347 B.C.). Plato was the seminal rationalist philosopher who emphasized thought as a means of understanding the world, and he de-emphasized empirical observation because it could be distorted by perception. He was a dualist who believed that the mind was a different and separate entity from the body. Understanding of how the mind and memory worked depended on understanding that the nature of innate, inborn knowledge was the foundation of human thought. Memory was the bridge between the perceptual world and the rational world of idealized abstractions (Viney & King, 1998).

Plato also provided the metaphor of memory as a wax tablet, holding the impressions of experience. This metaphor also conveys the idea that memory quality varies depending on the quality of the wax (the state of the person) and the pattern that is impressed (how well the information is encoded). The better the impression, the easier it is to retrieve it later or to compare it with other impressions. Furthermore, the wax can be altered or erased so that an impression is lost, thus conveying the concept of forgetting.

Plato's most prominent pupil was Aristotle (384–322 B.C.). Like any good student, Aristotle's ideas were at odds with his mentor. Specifically, whereas Plato was a rationalist, Aristotle was an empiricist who believed that reality itself, not an abstract, perfect realm, was the basis of inquiry. One of Aristotle's contributions is the idea that memories are composed of associations among various stimuli or experiences. As you will see, there are many theories of memory that are associationistic, such as accounts of priming, interference, or even the creation of false memories. There is a pervasive idea that understanding how various elements are mentally linked to one another can capture the structure and processes of memory.

These linking relationships often follow Aristotle's three laws of association: similarity, contrast, and contiguity. That is, memory associations provide links to ideas that are similar in nature, are the opposite on some critical dimension, or occurred near one another in time.

The desire to understand memory did not stop with these philosophers. This inquiry has been continuously pursued. For example, St. Augustine (354–430) spends a great deal of time in Book X of his *Confessions* on the topic of memory, covering the subject in a way that is familiar today. Some thinkers developed conceptions of memory that were often not pursued. For example, Robert Hooke (1635–1703) developed a surprisingly insightful theory of memory. However, his work was generally overshadowed by Sir Isaac Newton (1643–1727), whose work further hurried Hooke's ideas into obscurity (Hintzman, 2003).

Darwin and Evolution

One person who had a great impact on scientific thinking in general, including human memory, was **Charles Darwin** (1809–1882). Darwin, of course, is best known for his theory of natural selection, but his ideas influenced psychology as well (see the entire February–March 2009 issue of *American Psychologist*). The central idea is that, within a species, changes occur as a result of variation that can either be passed down to or removed from subsequent generations through the process of *natural selection*. Through this process, species develop features or abilities that allow them to become better adapted to their environments. The same could be said of memory. Many theorists are either implicitly or explicitly guided by the idea that memory has evolved to capture many major characteristics of the environment and to perform specific tasks (Glenberg, 1997; Klein, Cosmides, Tooby, & Chance, 2002; Shepard, 1984). Different types of memories capture meaningfully different types of information. Also, because many species are evolving along similar trajectories, nonhuman animals can sometimes be used to study issues of memory that require more control than is either practically or ethically possible with humans.

This evolutionary aspect of memory has an influence on how people think about the mind, behavior, and genetic influences. In some sense all human behavior has a genetic component (Turkheimer, 1998). The very existence of our brains in the interiors of our skulls requires that we have brain-building DNA, and all of our thoughts and memories depend on our biologically constructed brain. Any psychological state corresponds to a neural state. Thus, our thoughts and memories have an important genetic component. However, our DNA does not cause our brains to have the *exact* configuration that we have at the moment. This is due to our long history of experiences. Similarly, although our thoughts depend on neural hardware and processes, it does not mean that the most direct way to understand memory is by a detailed understanding of the underlying neuro physiology. That said, the more you understand the underlying neurological components and processes, the better you will understand the higher-order operations. For this reason, I include several descriptions of this influence to broaden your understanding.

Philosophy of Mind

Another important group of thinkers that has influenced ideas about memory are the British empiricists, including George Berkeley (1685–1753), John Locke

(1632–1704), John Stuart Mill (1806–1873), and David Hume (1711–1776). Perhaps the most significant of their ideas involve association, a concept originally conceived by Aristotle but worked up into grand form by the empiricists. Associationism maintains that memories are largely composed of interconnections among various simple concepts or ideas. The influence of this view is seen clearly in Chapter 10 when we discuss formal models of memory. This role of associations in memory can be easily illustrated. Things in the world are rarely treated by people as isolated entities or properties. Instead, we are often reminded of other, related experiences that included them. For example, when I eat a certain brand of cookies, I am reminded of my childhood because those were the kind of cookies my mother bought.

The empiricists' idea that memory is composed of associations has had a major influence on theories of human memory. However, the philosophical antagonists of the empiricists, the rationalists, including René Descartes (1596–1650) and Immanuel Kant (1724–1804), have also had an influence. While the empiricists characterized memory as a passive collection of associations built up from the environment, the rationalists took the view that the mind is actively involved in the building of ideas. This can be seen in various theories of memory that involve the active construction and reconstruction of memories, such as those found in schema theories (see Chapter 9).

Early Memory Researchers in Psychology

Psychology as an independent discipline arose in the second half of the nineteenth century. Since then many people have influenced memory research. While a few influential contributors are covered here, it should be kept in mind that the study of memory did not always move at a steady pace. Sometimes people develop ideas that have the potential to move the field forward but, for whatever reason, are not noticed at the time. These theories fall by the wayside, never to be heard from again. However, a few may capture the attention of future generations, who discover the earlier, neglected work. For example, in memory research, Richard Semon (1859–1918) had a theory of memory in the first decade of the twentieth century that incorporated many ideas about the process of retrieval. However, his contemporaries largely ignored these ideas and his insights were not appreciated until 70 years later (Schacter, Eich, & Tulving, 1978). Let's look at some people whose work had a more immediate impact.

One of the first true students of memory in a scientific form was **Hermann Ebbinghaus** (1850–1909). He is best known for his 1885 publication *Memory: A Contribution to Experimental Psychology*. This work conveys detailed studies of memory, using himself as both experimenter and subject. This was a time of psychological research when the study of one's self was more acceptable. Currently, it is viewed as more objective if an experimenter tests another person who knows little to nothing about the experimental hypothesis. There are still some people who test their own memories, but these efforts are rare.

Ebbinghaus tried to study memory in what he considered as pure a form as possible, in the absence of an influence of prior knowledge. To do this, he devised a test stimulus called the **nonsense syllable**, which is a consonant–vowel–consonant trigram that has no clear meaning in language. Nonsense syllables for English include PAB, SER, and NID. Ebbinghaus created and used about 2,300 of these. These nonsense syllables have been used by researchers to study memory for decades and they spent a great deal of effort studying them, even to the point where nonsense syllables were rated for meaningfulness (Glaze, 1928). For example, "BAL" is rated high in meaningfulness (because of "ball"), whereas "XAD" is rated very low.

Ebbinghaus memorized lists of nonsense syllables of various lengths, under various learning conditions, and for various retention intervals before he tested himself. (In some studies he did use some real words on the premise that it would have little effect.) For memory retrieval he would give himself the first nonsense syllable and then try to recall the rest in the list. Using this approach, he was able to discover a wide range of basic principles of human memory that have withstood the test of time, which are covered next. It should be noted that although Ebbinghaus discovered these principles using nonsense syllables, these same patterns are observed with all types of information.

The **learning curve** is the idea that there is a period of time for information to be memorized. It can be affected by a number of things, such as the amount of information to be learned. The learning curve is a negatively accelerated function in which most of the action occurs early on, with smaller and smaller benefits later on, so the largest amount of information is learned in the first segment. In the second, although more is learned, the gain is not as great as during the first. A similar description applies to the third segment, and so on. Furthermore, Ebbinghaus showed that how a person went about learning, in terms of the distribution of practice, influenced how well information was learned. Specifically, memory is better when practice is spread out over time, rather than lumped together—a distinction between what is known as **distributed practice** and **massed practice**.

The **forgetting curve** is the opposite of the learning curve. The forgetting curve, like the learning curve, is a negatively accelerating function. As we'll see in Chapter 3, most of what is forgotten is lost during the initial period. As time goes on, forgetting continues but at a slower pace. The more time that passes, the slower the rate of forgetting.

Forgetting is the most problematic aspect of memory, and the forgetting curve suggests that we are doomed, sooner or later, to lose all of our memories. However, this is not strictly the case. There is some knowledge that you've had for years and are unlikely to ever forget. This may happen by a process called **overlearning**, in which people continue to study information after perfect recall has been achieved, insulating the memory against forgetting. If there is substantial overlearning, forgetting may be delayed for quite some time, perhaps indefinitely.

When information has been forgotten to the point that nothing can be recalled with accuracy or reliability, it might seem that people must start at square one and repeat all of the previous effort. However, this is not the case. Ebbinghaus found that, after seemingly complete forgetting, subsequent attempts to relearn the information required less effort than the first time. The difference between the amount of effort required on a subsequent and initial learning attempts is called **savings**. The existence of savings is very important. It demonstrates that knowledge that appears to be lost may be residing somewhere in memory. It is no longer consciously accessible but it can still exert an unconscious influence on behavior—in this case, serving as a platform on which to build a new set of consciously available memories.

Another major figure in the study of human memory is **Sir Fredrick Bartlett** (1886–1969). Bartlett was, in some ways, the opposite of Ebbinghaus. Whereas Ebbinghaus was interested in memory independent of prior knowledge, Bartlett was directly interested in how prior knowledge influenced memory. He found that prior knowledge profoundly influences memory. He suggested that memories are often fragmentary and incomplete. When people are remembering, they are reconstructing the information from the bits that they have along with prior knowledge about similar circumstances. This reconstruction is guided by "schemas" (an idea also used by the Gestalt psychologists). Schemas are general world knowledge structures about commonly experienced aspects of life (see Chapter 9). To illustrate the effects of schemas, Bartlett had people read a story and then later try to recall it anywhere from immediately after they read it to several months or years later. What he found was that memories for the story became more fragmented, and its content was altered to make it more consistent with a stereotypical story.

TRY IT OUT

There are some fundamental characteristics of memory that can be understood even at this early juncture, such as the **forgetting curve**. The aim of this Try It Out section is to assess the forgetting curve. For this task, first create some lists of 20 or so words to use as your materials. When you generate these lists, try to keep the words similar in some way, such as all being from the same class of words (e.g., nouns or verbs), being similar in length (e.g., five to six letters long with two syllables), and so on. If you want, you can try other kinds of items, such as pictures, sentences, odors, or any other kind of materials that may interest you.

When you present the information to people, keep the presentation time constant for each item, such as three to five seconds. What is important here is the amount of time that has passed from when people first learn a list and when they later have their memory tested. A simple, straightforward way to do this is to test people immediately, after one hour, after one day, and after one week, although you can use other retention intervals. This critical thing is to have different periods of time between when you test people.

Try to have at least 12 participants for each period of delay. These can either be different people for each retention interval or the same people, tested on different word lists at the different time delays. If you go with the second option, it is best if people memorize a different list of words for each retention delay, and even better if you separate out the lists and memory test delays. That is, do not give people all of the word lists at once and then test them at different delays. This may confuse them. Instead, you might first give people the first list and then test them immediately. Then, you would give people the second list to learn and then wait an hour to test them. Then, give people the third list of words, and so on.

For the memory test, there are three ways that you can measure memory (see Chapter 3). They are recall, recognition, and savings. If all goes well, what you should find is that memory for the word lists will decline in a way that shows the greatest rate of forgetting soon after the list is encountered, and a slower rate of forgetting at longer periods of time.

To assess memory using **recall**, have people report all of the items that they can remember by either writing them down on a piece of paper, typing them into a computer, saying them aloud, or whatever works best for you. To score this, count up the number of items from a given list that were correctly reported. Plot the number correct as a function of the amount of time that had elapsed.

To assess memory using **recognition**, give people a series of items and have them indicate—”yes” or “no”—whether each one was learned earlier. Ideally, half of the items will be ones that they studied earlier, and the other half, called lures, would be similar items that were not studied. This can be done by having people mark “yes” or “no” next to a series of items on a piece of paper, having them respond to flashcards, showing people a series of PowerPoint slides, and so on. To score this, count up the number of studied items that were correctly identified and subtract any incorrect items that a person erroneously said “yes” to (to correct for guessing). Finally, plot the corrected recognition scores as a function of the amount of time that had elapsed.

To assess memory using **savings**, instead of having people study each item for a set period of time, have people repeatedly go over the list until they can recall the entire set from memory. Then, after memorization, wait a given retention period and have people relearn the list until it can be perfectly recalled again. To score this, calculate the difference in the memorization times used initially and after the retention interval. This difference is the savings score. Finally, plot the savings scores as a function of the amount of time that had elapsed.

Another prominent early psychologist was **William James** (1842–1910).[1] Much of his influence comes through his book *The Principles of Psychology* (1890/1950). James was a primary figure in the functionalist movement of early psychology. In terms of memory, James provided descriptions of memory that are remarkably similar to theories in use today. For example, his distinction between primary and secondary memory parallels the distinction between short-term and long-term memory. Similarly, he was one of the first academics to describe memory retrieval problems, such as the tip-of-the-tongue phenomenon (see Chapter 15), in which a person is not able to remember something, such as someone’s name, but has a strong feeling that retrieval is imminent.

Gestalt Movement

The **Gestalt** movement, primarily advanced by German researchers such as Wolfgang Kohler (1887–1967), Max Wertheimer (1880–1943), and Kurt Koffka (1886–1941), suggested that strictly reductionistic approaches to mental life were incomplete. Instead, one needed the idea that complex mental representations and processes have a quality that is different from the component parts that make them up. This is not to say that the Gestalt psychologists rejected reductionism. They most certainly did not. Instead, they argued that an understanding of more complex phenomena was important in its own right because it could be qualitatively different. For example, a melody is something that is qualitatively different from the individual notes that make it up, although it is certainly very dependent on them.

One of the ideas of the Gestalt movement that influences thinking about memory is that the whole is *different from* the sum of its parts. This can be seen in the idea that memories are built up of a configuration of simpler elements to take on a new quality. Gestalt psychologists also noted that the observed behavior of people depends on both the context in which they find themselves, as well as a frame of reference. This is reflected in the context effects that are observed in memory, and perspective effects such as the hindsight bias. Moreover, because our context and goals can change, the way we use and organize our memories change according to these demands as well (Danziger, 2008).

A final concept to come out of the Gestalt movement is the idea that mental representations are isomorphic. That is, their mental structure and operation are analogous to the structure and function of information in the world. This idea is clearly seen when spatial memory is discussed (see Chapter 11). The idea is that the structure of a memory trace reflects the structure of the event, as it would be experienced, although the memory is not as complete. It should be noted that this isomorphism was a functional one. The memory trace functioned “as if” it has the same structure as external events, not that it actually did.

Behaviorism

As we will see in Chapter 6, there are many aspects of memory that operate on a basic and unconscious level. Some of these involve the encoding, storage, and retrieval of relatively simple contingencies that fall under the heading of “conditioning.” This was the domain of the behaviorists. **Behaviorism** is a school of thought that sought to bring greater credibility to psychology as a science. It was a line of thinking that had a strong grip on psychology for much of the early to mid-twentieth century. Part of this effort was to avoid mentalistic constructs because they could not be objectively observed. Although the workings of the mind could not be observed, behavior could be, so much of the experimental work done during the behaviorist era did not directly address issues of memory. However, there were some important insights and discoveries that are relevant here.

Two salient forms of conditioning are classical and operant conditioning.

Classical conditioning is a form of memory that allows one to prepare for contingencies present in the environment, whereas operant conditioning allows one to remember the consequences of one's own actions. Both of these came into the vocabulary of psychology early on in the twentieth century. Classical conditioning was first described by the Russian physiologist Ivan Pavlov (1849–1936), who won the Nobel Prize for his work on digestion. Operant conditioning was first described by an until then little-known American named Edward Thorndike (1874–1949), who discovered these principles starting with his work as a graduate student.

The discovery and study of forms of conditioning are important because for decades they shaped much of the research in learning and memory. There was great interest in studying the principles that guided these forms of learning and the effects they had on behavior. One of the salient qualities of classical and operant conditioning is that one can take these principles pretty far without having to posit much about what is going on mentally. One can just observe the stimulus conditions and the responses produced by an organism.

Despite the general anti-mentalistic view of the behaviorist era, there were some behaviorists who had important insights into issues of memory. For example, Edward Tolman (1886–1959) did a number of studies with rats running through mazes. According to strict behaviorist analyses of maze running, what the rat learns is to make specific turns at specific junctures. Each turn that the rat makes in the maze would be reinforced or not. If this is true, then any change in the maze should cause the rat to need to learn the route all over again. However, Tolman observed that rats adapted to changes very quickly. This led him to suggest that his rats had a mental representation in memory for that spatial location. Tolman called this the "mental map." The rats could consult this mental map to adapt to the changes in the maze. Thus, working within the behaviorist context, people such as Tolman were able to bring a discussion of memory and mental activity back into mainstream psychology.

PHOTO 1.2 *During the behaviorist era, there was a heavy emphasis on observables, such as the behavior of a rat running a maze, and a de-emphasis on unobservables, such as the memory and thinking that goes on in the mind*

Source: irin717/iStock/Thinkstock

Tolman was a molar behaviorist, although the term he preferred was “purposive behaviorism.” That is, he was interested in larger behaviors as opposed to the more microscopic behaviors that interested many of his colleagues. An example of a molar behavior might be something like getting to the end box of a maze or going to a movie, whereas a microscopic behavior might be an action like “turn left.” This interest in molar behavior can be seen in an approach to memory that takes into account the goals and context of a person in the memory situation.

Verbal Learning

The **verbal learning** tradition existed in the context of a behaviorist psychology and stemmed from Ebbinghaus’s work with nonsense syllables. The term “verbal learning” itself reflects the behaviorism of many of its practitioners, although what was being studied was a form of memory. Because of this context, these studies often had clearly defined stimulus and response components. Memorization was referred to as “attachment of responses to stimuli” and forgetting was “loss of response availability.” (For a summary of verbal learning and its relationship to memory, see Tulving & Madigan, 1970.[2]) The verbal learning tradition was a way to study memory during the anti-mentalistic era of behaviorism.

One of the dominant methods in the verbal learning tradition is **paired associate** learning, a paradigm developed by Mary Calkins (1894). In this approach, people memorize pairs of items, often words, letters, or nonsense syllables. An example of a pair would be “BIRD–FANCY.” During testing, people would be presented with the first item of the pair and would be told to produce the second (e.g., “BIRD–?”). The first item served as the stimulus and the second as the response.

There were many variations on this theme. The simple A–B paradigm would present people with a list of paired associates and have them recall the B items in the presence of the A cues. Other paradigms are more complicated, where people must learn a second list of items. If this second list is unrelated to the first, this is an A–B C–D paradigm (easy). An example of this would be learning the pair “BIRD–FANCY” in the first list and “TABLE–ARROW” in the second. If the second list retains the initial cues with the first list, it is an A–B A–D paradigm (hard). An example of this would be learning the pair “BIRD–FANCY” in the first list and “BIRD–ARROW” in the second. An alternative is to have the second list be combinations of the A items with synonyms of the B items, called an A-B A-B’ paradigm (very hard). An example of this would be learning the pair “BIRD–FANCY” in the first list and “BIRD–DRESSY” in the second. Finally, if there are recombinations of the A and B items from the first list, this is an A–B A–Br paradigm (very, very hard). An example of this would be learning the pairs “BIRD–FANCY” and “TABLE–ARROW” in the first list and “BIRD–ARROW” and “TABLE–FANCY” in the second. Often what researchers are assessing is the effects of interference of prior learning on new learning. Issues of interference continue to be of interest and some still use paired associate learning. We’ll see some of these ideas explored in the sections on interference in Chapter 8.

Early Efforts in Neuroscience

Memories are stored in the brain and the brain is a complex and busy place. So where exactly is each memory stored? Is it possible to locate individual memories in the brain? This is the basic question asked by neuropsychologists such as **Carl Lashley** (1890–1958). Lashley (1950) did a series of studies in search of the “engram”—the neural representation of a memory. Lashley first trained rats to run through a maze and then surgically removed part of the rats’ brains. After the rats recovered from the surgery, they were placed back into the maze. If memories for the maze were localized in one part of the brain, then destroying that part would destroy the memory and the rats would then run the maze just as if they were entering it for the first time. The major outcome of these studies was that, no matter what part of the brain was removed, these rats were able to perform better than control rats that were placed in the maze for the first time. The critical factor was how much tissue had been removed, not where (see Figure 1.1).[3] This led Lashley to conclude that engrams were not localized in one part of the brain but are distributed throughout the cortex. While more recent work has shown that some forms of memory may be localized in different parts of the brain, the general conclusion that many different and distributed parts of the brain are used during memory processing is well supported.

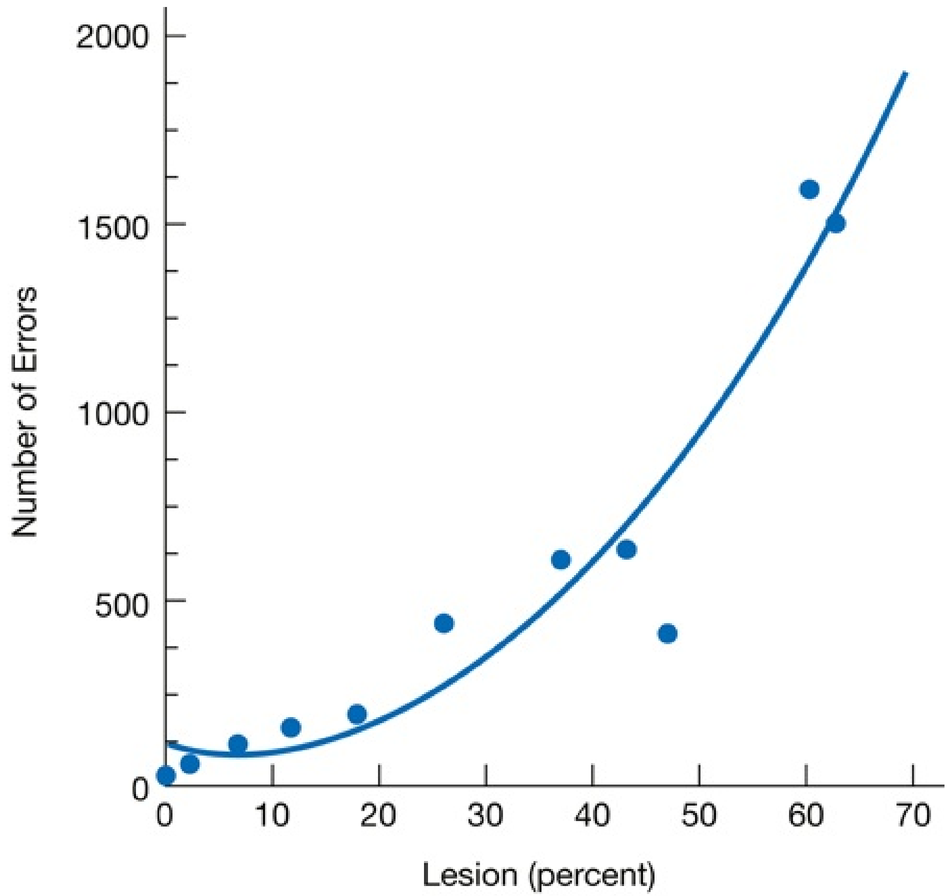

FIGURE 1.1 *Results of Lashley's Experiment with Brain Ablation*

Source: Lashley, K. S. (1950). In search of the engram. *Symposia of the Society for Experimental Biology: Physiological Mechanisms of Animal Behavior* (Vol. 4). New York: Academic Press

In addition to understanding what different parts of the brain do, it is important to understand how the brain works. That is, how do the interconnections among neurons influence memory? One of the pioneers along this line of research was **Donald Hebb**(1904–1985). Through his classic book *The Organization of Behavior* (1949), Hebb became one of the forerunners of computational neuroscience—the mathematical modeling of brain activity. According to Hebb, memories were encoded in the nervous system in a two-stage process. In the first stage, neural excitation would reverberate around in cell assemblies. A collection of cells that corresponds to a new pattern or idea would be stimulated and this stimulation would continue for some time. In the second stage, the interconnections among the neurons would physically change, with some connections growing stronger. The classic phrase here is “neurons that fire together, wire together.” This is similar to the idea of long-term potentiation, discussed in Chapter 2. It takes some time for memories to move from stage 1 to stage 2. This is why if people suffer a trauma to the brain, such as a blow to the head, they may lose recent memories (see Chapter 18). In addition, Hebb’s ideas of neural organization and change help lead to the development of computational models of the nervous system, such as the parallel distributed processing (PDP) models, which are discussed in Chapter 10.

The Cognitive Revolution

Over time, psychologists became frustrated with the constraints of behaviorism. There was a desire to study mental activity as mental activity, not as a black box between the input of the stimulus and the output of the response behavior. The **cognitive revolution** of the 1950s and 1960s marked a return of mental states to legitimate study. It made the study of memory palatable once again.

Many people contributed to the cognitive revolution. We focus here on one whose efforts serve as an example of the work and ideas that brought about this change. George Miller (1920–2012) provided a number of important findings for memory research, such as his work on the capacity of short-term memory in his paper “The Magical Number Seven, Plus or Minus Two” (Miller, 1956). This work took the idea of mental processing seriously and demonstrated how it was a limited system, much a like a computer’s processing is limited by the amount of memory it has. These studies were some of the first to show that memory could be studied with the methodological rigor that the behaviorists were so fond of.

Miller also showed that how people mentally organized information influences memory. The more highly organized a set of information was, the better the memory. In other words, how information is actively thought about later affects memory. In addition, the knowledge that a person has stored in long-term memory can influence current memory performance in profound ways. Thus, work by Miller, and people like him, showed that, in order to understand how memory works in the current situation, one must understand how it is structured over the long term.

Stop and Review

The study of memory stretches back to ancient times, with philosophers such as Plato and Aristotle. Other important thinkers to influence thought about memory include St. Augustine, Robert Hooke, and Charles Darwin, as well as the various philosophy of mind figures. The scientific study of human memory began with people such as Hermann Ebbinghaus, Sir Frederick Bartlett, and William James. Current thinking and research is also guided by work of the Gestalt psychologists and the behaviorists. The verbal learning tradition, which emerged out of the behaviorist era, and efforts in neuroscience evolved into our current cognitive science approach to memory.

THE MODAL MODEL OF MEMORY

The standard model of memory, or the **modal model** (Atkinson & Shiffrin, 1968), is a heuristic guide for understanding how memory works. It has successfully limped along for years as a framework for discussing issues about how information is stored over time. This model has four primary components: (1) sensory registers, (2) short-term store, (3) long-term store, and (4) control processes. An outline of the model is shown in Figure 1.2.

The first component, the **sensory registers**, is best thought of as a collection of memory stores. Each of these stores corresponds to a different sensory modality. For example, there is a sensory register for vision, one for audition, one for touch, and so on. The world is full of information that is in a constant state of flux. Our sensory registers allow us to hold on to this information for brief periods of time to determine if it is worthy of further attention. If we did not possess such memory stores, our minds would be constantly locked into only the very current state of affairs. We would not be able to detect patterns that involve very brief memories, such as determining that two frames of a film can be interpreted as continuous movement, or that a sequence of sounds forms a word.

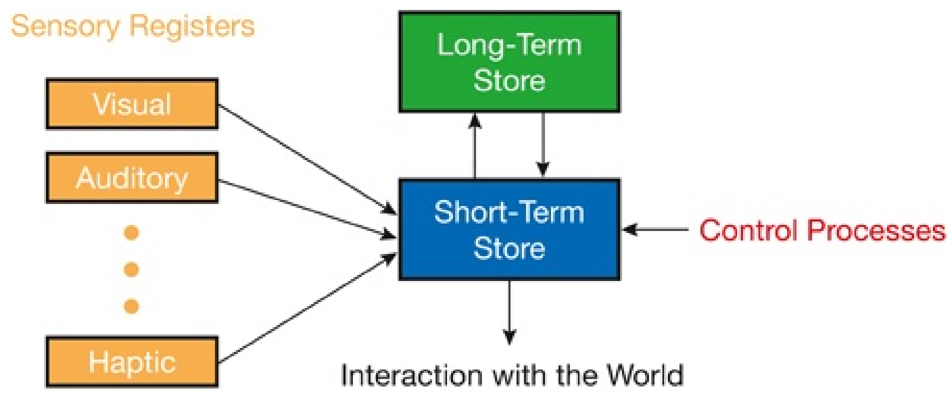

FIGURE 1.2 *The Modal Model of Memory*

Adapted from: Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. *The Psychology of Learning and Motivation*, 2, 8–195

Once information has been attended to, it needs to be kept in the current stream of thought. Because what we are currently thinking about constantly changes, this information needs to be kept available for a short period of time. This **short-term memory** generally retains information for less than a minute if nothing is actively done with it. If consciousness is associated with any part of memory, it would be the information in short-term memory. This is knowledge that is either currently in conscious awareness or just beyond it. Another characteristic of short-term memory is its capacity—the amount of information that can be held in an active state. This amount is humblingly small—somewhere on the order of seven items. The topic of the sensory registers and short-term memory are considered in detail in Chapter 4.

The third part of the modal model is the idea that there are **control processes** that manipulate information in short-term memory. This can include rehearsing information, transferring knowledge to and from long-term memory, or perhaps even reasoning. This component of memory makes it an active participant in reality rather than just a passive absorption and retrieval mechanism. The idea that control processes work with knowledge in the service of some goal has led to the idea that short-term memory should be considered more of a working memory system. Issues of working memory are considered in Chapter 5.

The fourth component of memory—the one that interests most people and that much of this text is devoted to—is long-term memory. **Long-term memory** encompasses a wide variety of long-term knowledge and different ways of using that knowledge. Issues of long-term memory are covered extensively in Chapters 6 through 18.

Again, it should be noted that the modal model is a heuristic for thinking about memory, but it is not an accurate theory of memory. For example, incoming information does not need to pass through short-term memory to reach long-term memory. Instead, the information may activate knowledge in long-term memory, which is then actively manipulated as short-term memory (van der Meulen, Logie, & Della Sala, 2009).

Stop and Review

The modal model of memory is a heuristic that continues to be used as a guide to discuss memory. This model includes the sensory registers, a short-term memory system that holds small amounts of information for short periods of time, usually under a minute, control processes for manipulating information, and long-term memory system.

Improving Your Memory

At this point, we have not covered much on how memory works. Still, this section outlines some basic principles that you can follow to help improve your learning and memory in this and any other class. Many of these points touch on issues that are discussed at different points in the book. For now, just a few "best practices" are listed so that you can do better in your classes, perhaps with less time and effort (because you will not waste your time on things that don't work). You should:

- Read the assignment **before** you come to class. You only have one opportunity to hear a lecture. Reading the material ahead of time gives you a better foundation to identify what is more or less important in a lecture, and what it means. The more you can remember from a lecture, the less time and effort will be needed later.
- **Preview** the text prior to reading. Often sections of a chapter have headings, and there are key terms set off in bold. If you know what ground will be covered prior to reading, you can build a scaffolding in your mind ahead of time. Then, as you read, you can fill in this mental framework, allowing you to better retain what you are reading.
- Come up with **questions** to have in mind as you read. Seeking answers to these questions helps you process and remember the material. If you write these questions down ahead of time, this small amount of extra

effort at the beginning can save you more effort later.

- Make sure that you **read** the text carefully, trying to link up the material with what you already know and making sure you understand new words and jargon. If you give yourself enough time to learn as you are reading, you will remember it better and save yourself time later.
- After reading, try to **recite** answers for the questions that you came up with ahead of time. If you wrote them down before reading, this will be easier. If you can answer those questions, then you can be more confident that you have learned the material. However, if you struggle, then this high-lights just which aspects of the material were not well learned.
- Another good strategy is for you to **produce** something by writing down a summary of the material you read. This sounds like a lot of work. However, doing this will help organize the material in your mind, and save you study time later. Even the act of saying something aloud can also boost memory to some degree.
- Much of what you learn can be forgotten. To help maintain this knowledge, you will need **review** the material again to boost knowledge that may be weak or forgotten.
- When you study, try to do so in a **quiet** setting. This will minimize competition for your thoughts and allow you to better learn the material. Also, try to study in **different places** and at **different times** of the day if you can. This can help the knowledge from being tied to a specific setting. You want the things that you are learning to be available under any setting, such as when you are taking an exam.
- Humans are visual animals. So, if you are having a hard time learning something, try to form a **mental image** in your head. This may make it easier to remember, especially if you can imagine several things interacting.
- Try to spread your study time out is a **distributed** manner. Cramming is not effective for long-term learning. If you study your class materials every day, you will learn it better and will need to spend less time later trying to relearn things that you had forgotten.
- Much of your study time will be done alone. However, if you can find other people to study with, this can aid learning and memory. First, after class, **compare** your notes with someone else’s. This helps you identify material that you may have missed. Also, if you can, meet with people to quiz each other over the material. Ideally, this would be done about once a week. The act of **generating** questions to ask people improves your

memory, and the act of **testing** yourself also improves memory. Quizzing each other will also allow you to identify those aspects of the material that you do not know well.

- Finally, there are many neurological processes that help memory that occur when you **sleep**. If get enough sleep at night, you will have better memory for the class material. Relatedly, if you are fortunate enough to be able to take a nap during the day, this can be helpful too.

MULTIPLE MEMORY SYSTEMS

As is illustrated by the modal model, memory is not unitary. It has several sub-components that have evolved, as a result of selection pressures, to handle different jobs (Klein et al., 2002; Sherry & Schacter, 1987). A number of classifications schemes for long-term memory can be identified. One is Tulving's (1985) **triarchic theory of memory**, shown in Figure 1.3. This view divides long-term memory into three classes: nondeclarative, semantic, and episodic. These divisions reflect the different tasks required of memory, as well as different levels of control and conscious awareness.

Procedural memory is an evolutionarily old system. Even primitive organisms have some kind of procedural memory. Some people refer to this as the nondeclarative memory, and have grouped semantic and episodic memory together as declarative memory. This **declarative–nondeclarative** distinction is reflected in the organization shown in Figure 1.4. Declarative memory refers to memories that are easy for a person to articulate and talk about. In contrast, nondeclarative memory refers to memories that are difficult to articulate but that still influence our lives. As can be seen in Figure 1.4, nondeclarative memories can be divided into different types, and in Chapter 6 we discuss many of these. One type of nondeclarative memory is the procedural memory of Tulving's classification. This is memory for how to do things, like ride a bicycle or speak your native language. However, other types of memory are also included in this category, including unconscious, implicit memory processing. This memory system is described as *anoetic* (a: "no"; -noetic: "thinking") in Tulving's system because it does not require conscious awareness.

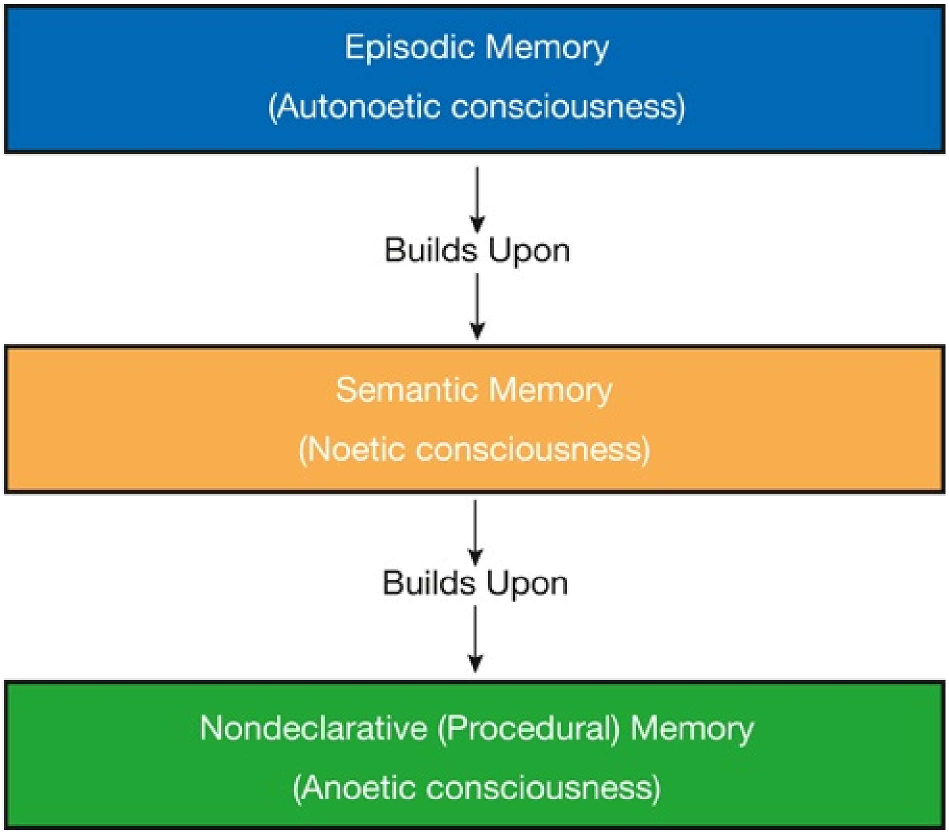

FIGURE 1.3 *Tulving's Triarchic Theory of Memory*

Adapted from: Tulving, E. (1985a). How many memory systems are there? *American Psychologist*, *40*, 385–398

As shown in Figure 1.4, declarative memory can be divided into two categories as defined by the **episodic–semantic** distinction (Tulving, 1972). Semantic memories are generalized and encyclopedic, and are not tied to a specific time or place. This is stable knowledge that you share with your community. For example, knowing what a bird is, what a stop sign means, and what you do in a restaurant are all semantic memories. Semantic memories are highly interrelated and are forgotten rather slowly once established. In Tulving's triarchic theory, semantic memory is *noetic* ("thinking") because it requires conscious awareness. You have to be consciously aware to know that an object is a bird or a tree and that it is similar to other members of that category.

Episodic memories refer to specific episodes or events in our lives. They are tied to the time and place in which the information was learned. For example, where did you go on your first date? Who told you that funny joke? Did you just see the word "apple" in a list of words? Also, unlike semantic memories, episodic memories are more compartmentalized and forgotten very rapidly. Episodic memory uses *auto noetic* (auto: "self"; -noetic: "thinking") knowledge in Tulving's triarchic theory because it requires knowledge of the self. For example, to know whether you've recently seen an action film, you need to have some memory of yourself as a separate identity to which past events can be referenced. In fact, neurological measures, such ERP recordings (see Chapter 2), show different types of brain activity for memories that refer to the self in some way compared to semantic memories (Magno & Allen, 2007).

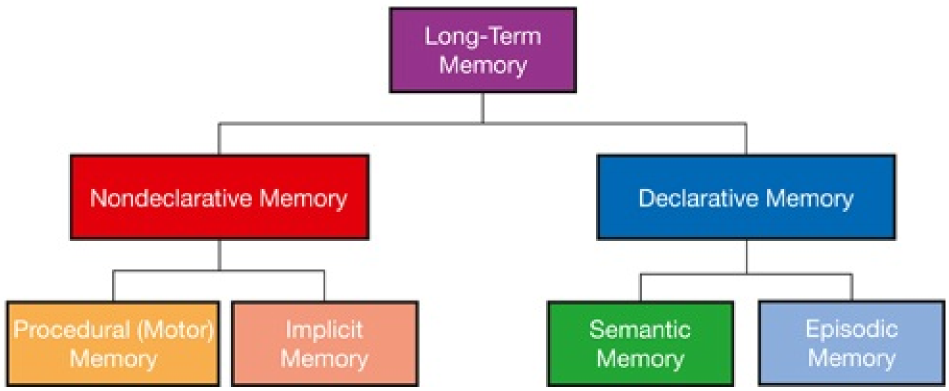

FIGURE 1.4 *The Division of Long-Term Memory Systems*

Adapted from: Squire, L. R. (1988). Mechanisms of memory. Science, 232, 1612–1619

In addition to the different types of memory systems, we can also point out differences in how people use their memories. One difference is the **explicit–implicit distinction** (Schacter, 1987). The important point here is how information is retrieved from memory, not the content of the information. Explicit memory refers to when a person is actively and consciously trying to remember something. When you are trying to recall someone's name or when you recognize a suspect in a police lineup, this is explicit memory. Implicit memory refers to when a person is unaware that memory is being used. For example, to be able to read, you need to remember what the various squiggles on a page correspond to. However, you don't really feel like you are pulling information out of memory to do this, and yet you are. Even though most of this book is dedicated to issues of explicit memory, much of our lives, both thinking and action, are governed by implicit memory. The fact that familiar things are recognized more quickly, are preferred in choices, and guide our thinking are all examples of the influence of implicit memory.

Stop and Review

Memory is divided into multiple systems that do different things with different types of information. These divisions may capture levels of consciousness awareness, as with the triarchic theory, and include the declarative–nondeclarative distinction and the implicit–explicit processes distinction.

RECURRING ISSUES

Before we move on to the specific topics, there are some issues that bear highlighting. These issues recur throughout the chapters, so it is helpful to alert you to them.

Neurological Bases

Memory exists as a property of the nervous system. The better you understand how the nervous system operates, the better you can understand memory. If nothing else, knowing that a theoretical mental process can be associated with a real neural process lends confidence to one's findings and ideas. As we advance into the future, cognitive neuroscience becomes more and more important.

Emotion

A growing trend in cognitive science is to look at the influence of emotion. More memory researchers are incorporating emotion into their theories (see Kensinger, 2009). In general, memory is better for emotional materials. Emotion facilitates memory consolidation as well as (1) increasing attention to emotional aspects of events, (2) making event memories more distinct, and (3) resulting in more information organization (Talmi, 2013). Certain topics will present findings that are critically dependent on emotion.

Multiple Memory Sources

Memory often uses multiple sources on nearly any memory task. This is reflected in what are known as **fuzzy trace theories** (e.g., Brainerd, Reyna, & Mojardin, 1999), in which there are at least two memory traces involved in any act of remembering. One is a memory that contains detailed information. The other captures more general information. Remembering reflects a combination of these. The detailed memory trace dominates when a person has a good memory of an event. In contrast, the general memory trace dominates when memory for an event is poor or if knowledge is being used in a general way, such as trying to remember what a flywheel is.

Embodied Cognition

Embodied cognition[4] can mean many different things (Wilson, 2002), but the basic idea is that mental activity is grounded in the type of world our bodies inhabit and the ways we use our bodies: our sensory and motor processes. Memory is affected by the situations people find themselves in, such as using context to help guide encoding and retrieval. Also, memory often operates in real time as events are unfolding. As anyone taking an exam knows, memories need to be adequately retrieved in a set time limit.

Scientific Rigor and Converging Evidence

Memory is a tricky thing to study. Each person's memories are different from everyone else's. There are also aspects of memory that are qualitatively distinct. To have the clearest picture of what our memories are like, and who we are, we need to take as objective a view as possible. We need to avoid being led astray by our biases, momentary intentions, and other prejudices. Taking a rigorous, scientific approach can do this. Psychology, after all, is a science. To emphasize this, various approaches or methods of looking at the data from memory experiments are presented throughout the book to illustrate how the data from memory studies can be analyzed and interpreted to gain better insight into the depths of our mental storehouses. Also, we will see that opinions and theories formed as a science are better supported when evidence comes from different methods of collecting and analyzing data. If these multiple sources of information are consistent with the same explanation, this gives us greater confidence that the theory is closer to the truth. This is known as **converging operations**. This is important as ideas about memory that emerge largely from relatively limited and simplistic methods and views can distort our thinking about and understanding of human memory (Hintzman, 2011).

Stop and Review

There are a number of recurring threads that reappear across the various topics discussed that represent emerging ways of thinking about memory. These include an increased desire to understand the neurological underpinnings of memory, the involvement of experienced emotions in memory, the division of information across multiple memories, and the need to understand how memory operates in the real world. All of the topics in memory are approached from a scientific perspective that seeks to derive answers about memory that help us have an accurate and durable understanding of ourselves.

PUTTING IT ALL TOGETHER

Understanding memory is one of the most introspective tasks you can undertake. By looking at how your memories are created, structured, stored, and retrieved, you can gain a better insight into who you are. The study of memory, however, is difficult. Even with explicit definitions of learning and memory, there are many things that go uncaptured. Memory is complex and not open to direct observation, so you need metaphors to capture its essential qualities. People have been trying since ancient times to uncover the mysteries of human memory. The scientific study of memory began in earnest with work by Ebbinghaus. Using himself and lists of nonsense syllables he discovered several basic principles of memory. Bartlett used the concept of a schema to capture general knowledge of the world, and the Gestalt psychologists understood the impact of context or setting on what is remembered. Finally, the behaviorists provided an approach of experimental rigor that continues to be used. The verbal learning tradition, along with efforts in neuroscience, led to the emergence of the current cognitive tradition. Over the past several decades we've gained a clearer and consistent picture of what memory is. There are different kinds of memory that cover different spans of time and are for processing different types of information. This book surveys human memory, often touching on neuropsychological issues, the impact of emotions, and multi-trace influences, all within the context of using appropriate scientific rigor.

STUDY QUESTIONS

1. What do the terms *learning* and *memory* mean in the context of this chapter? How are they referring to similar things? How do they diverge?
2. Why do we need metaphors for memory? What are some metaphors? What do they tell us about the nature of memory?
3. What were some of the major figures and some of the major schools of thought that dominated thinking about human memory? What were the contributions of each?
4. What are some of the major components of the modal model of memory?

How do these components interact?

5. What are some of the major divisions of human memory? What sort of processing is done by each of those divisions?
6. What are some of the emerging themes that will be recurring at various points in our discussion of memory?

KEY TERMS

- behaviorism
- Carl Lashley
- Charles Darwin
- cognitive revolution
- control processes
- converging operations
- declarative-nondeclarative distinction
- distributed practice
- Donald Hebb
- embodied cognition
- engram
- episodic-semantic distinction
- explicit-implicit distinction
- forgetting curve
- fuzzy trace theories
- Gestalt psychology
- Hermann Ebbinghaus
- learning
- learning curve
- long-term memory
- massed practice
- memory
- metaphors for memory
- modal model
- nonsense syllable
- overlearning
- paired associates
- recall

- recognition
- savings
- sensory registers
- short-term memory
- Sir Fredrick Bartlett
- Tulving’s triarchic theory
- verbal learning
- William James

EXPLORE MORE

Here are some additional readings that you can explore to provide yourself with better insight into the history and basics of human memory.

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NOTES

1 James is so highly regarded that it is not unusual to find a quote by James leading off a research or review article, particularly by Americans.

2 This chapter by Tulving and Madigan is one of the most wonderfully snarky papers I’ve ever read. I wish I could write papers like this.

3 A similar study was done with pigeons by J. P. Flourens in the nineteenth century, as reported by Danziger (2008).

4 Although the term “grounded cognition” (Barsalou, 2008) is more descriptive and inclusive, we use the phrase “embodied cognition” to be consistent with the majority of the literature.

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CHAPTER 2

Neuroscience of Memory

How are memories encoded? Where are they stored? How are they retrieved? Using the computer analogy, thoughts and memories are the software and data, and the nervous system is the hardware. A person can understand many aspects of the software without knowing much about the hardware. How many computer users don't really understand how their device works but can still operate the software? That said, to gain a truer insight into the software, how it represents and processes information, and why some processes are fast and others are slow, one needs an understanding of the hardware. The same is true for memories and the nervous system.

Memory is an **emergent property** of the nervous system. That is, it is not a property of the individual neurons, but it emerges when they work together. To illustrate the idea of what an emergent property is, think of six square boards. None of the boards by themselves has the property of containment. However, when they are arranged to make a box, then it is possible to place something inside it. The property of containment emerges out of the arrangement of the elements that lack that property individually (see Minsky, 1986).

Without a basic understanding of the nervous system, your knowledge of memory will be limited. The aim of this chapter is to provide information about the major components of the nervous system and how they are involved in memory. We first consider neural structure, how neural communication occurs, and how this changes as a result of experience (memory). After that, we skip to higher levels of processing and discuss some of the major components of the brain, such as the cortex. Finally, we examine ways to study the underlying neurobiology and how findings in memory research are related to neurological structures and processes.

NEURONS

To adequately understand how underlying neurophysiology relates to psychological experience and the operation of memory, it is a good idea to have a working understanding of the nervous system. Let’s first look at the basic components of individual neurons, followed by a consideration of neural communication.

Neural Structure

The most basic parts of the nervous system are neurons. A **neuron** is a specialized cell for the transmission and retention of information. The structure of a neuron is shown in Figure 2.1. Some of the neuron’s components are shared with other cells. For example, the neuron has a cell body, or **soma**, which contains all of the general cell processing components, such as mitochondria, ribosomes, RNA, and so on.

Other cell structures are important for the specialized jobs of neurons. Extending out of each neuron are dendrites. **Dendrites** are used for receiving signals either from sensory cells or from other neurons. Generally speaking, dendrites collect information for the neuron. Neurons also have another structure protruding from them called an axon. **Axons** transmit information out of the neuron either to other neurons or to muscles and glands. Thus, axons are responsible for sending information out of the neuron.

At the end of each axon are nodules called **terminal buttons**, which contain the neurotransmitters. **Neurotransmitters** are the chemicals that are used to send signals to other neurons. Because axons can sometimes be quite lengthy, to avoid the loss or confusion of signals some neurons have axons that are encased in a fatty substance known as a **myelin sheath** that acts as an insulator. If a neuron has a myelin sheath, the myelin is not created by the neuron but by glial cells associated with it.[1] The myelin sheath is not continuous but has gaps along its length called the **nodes of Ranvier**. These gaps facilitate the transmission of information within a neuron by allowing the neural signal to jump from one point to the next (one gap to the next) without having to continuously traverse the entire length of the axon. Thus, the distance that the neural signal travels is functionally shortened, allowing the neural signal to travel more quickly.

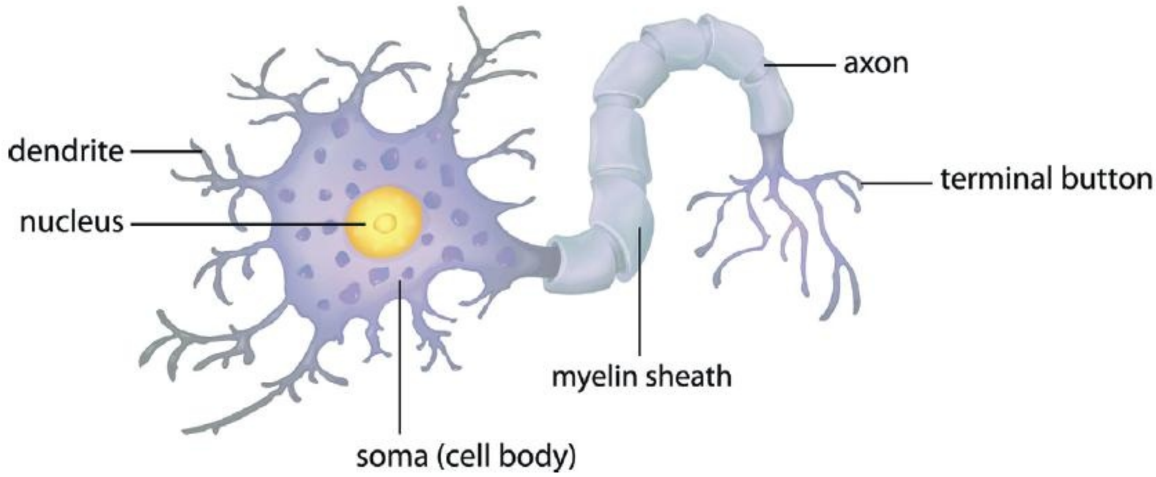

FIGURE 2.1 *A Neuron*

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The Action Potential

Let's now look at the transmission of information. Neural communication can be roughly broken down into two components, one electrical and the other chemical. The electrical component occurs within the neuron itself and is called the **action potential**. When a neuron is sufficiently stimulated, an action potential occurs and the neuron is said to "fire" (see Figure 2.2). When a neuron is not being stimulated, it has a resting electrical charge of –70 mV (millivolts). This is because there are a number of negatively charged ions in the interior of the neuron. When a neuron is stimulated, there is a depolarization of its electrical potential. If this depolarization shifts the neuron's electrical charge in a positive direction, the electrical charge may reach –50 mV. At this point there will be a dramatic change in the charge of the neuron, where it shifts to +40 mV. This is the action potential. After a neuron fires, there is a brief recovery period during which it prepares itself to fire again and resets itself at the resting potential of –70 mV. This electrical charge is the basis of some of the neuroimaging techniques described later in this chapter. It should be noted that the action potential operates on the all-or-nothing principle. That is, there is either an action potential, which is always the same, or there is no action potential.

The action potential does not exist in the entire body of the neuron at once. Rather, there is a wave of activity flowing down the axon. When a neuron fires, sodium ions in the surrounding extracellular fluid flood into the neuron because the depolarization of the neuron causes sodium “gates” on the cell membrane to open. The sodium ions are positively charged and this is what produces the positively charged action potential. The electrical wave flowing down the axon is the wave of sodium gates opening and allowing these ions to enter the cell, much a like a row of dominos falling down. Each domino causes the next to falter. Immediately behind this wave of positive electrical charge, there is a second wave. This is a wave of potassium ions being forced out of the cell. This is part of the beginning process of the cell recovering its resting potential level of electrical charge.

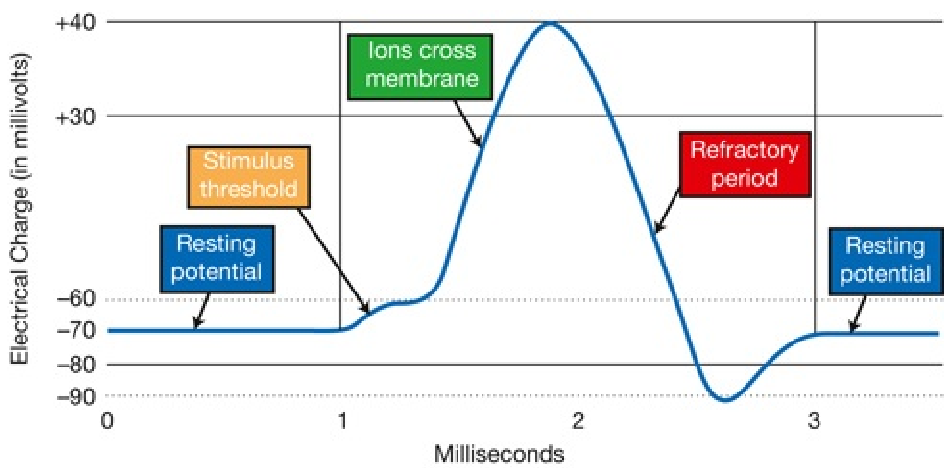

FIGURE 2.2 *The Action Potential Over Time*

Neurotransmitters and the Synapse

The chemical component of neural communication occurs at the **synapse** between two neurons. Although a single neuron may communicate with large numbers of other neurons, especially in the cortex, there is no direct physical connection between them. There is a small gap between one neuron and another. This synaptic gap is about 100 to 200 angstroms wide (1 angstrom = 1/10,000 of a millimeter). Neurons communicate across the synapse using chemicals called neurotransmitters. Neurotransmitters reside in the terminal buttons of one neuron, inside synaptic vesicles, and are forced out into the synapse when there is an action potential. These neurotransmitters are often absorbed by the subsequent neuron, altering its electrical potential.

While all neurotransmitters are involved in memory in some way, either directly or indirectly, some are more important than others. One is **acetylcholine** (**ACh**). When acetylcholine effects are enhanced, memory can improve, and it declines when acetylcholine effects are suppressed (Mishkin & Appenzeller, 1987). Acetylcholine may work to enhance the strength of synaptic potentials during long-term potentiation (see later). **Glutamate** (**Glu**) is a critical excitatory neurotransmitter involved in the alteration of synapses and creating new memories. In comparison, gamma-amino butyric acid (**GABA**) is an inhibitory neurotransmitter, also critically involved in new memory formation. GABA is strongly related to glutamate in that GABA is formed by modifying the glutamate molecule. **Norepinephrine** is involved in the consolidation of memories and **dopamine** is important to memory pro cessing. Part of the problem with a condition like Parkinson's disease is the low level of dopamine available.

There are two general classes of neurotransmitters. Excitatory neurotransmitters encourage the subsequent neuron to fire, causing the ion gates on the neuron's cell membrane to open and let in the sodium ions. In contrast, inhibitory neurotransmitters encourage the subsequent neuron to *not* fire, encouraging the ion gates to stay closed. At first, this may seem odd. If the goal of neural communication is to transmit information, why would one neuron inhibit the firing of a subsequent neuron? The reason is that one-way information is coded in the nervous system is as a pattern of activity across a wide set of neurons. To create this pattern, some neurons need to be firing and others not. For example, computers code information as a pattern of 1s (on) and 0s (off), and this is roughly the same idea, although in a different form and with much greater complexity. Waves of neural firing that are dominated by excitation and little inhibition can occur in the brain and are called seizures.

Another important point about neurotransmitters is that they do not operate alone. Other chemicals can affect them. For example, neuromodulators can accentuate or diminish the influences of neurotransmitters. This adds a level of variability to neural processing. Also, while some neurons interact with the body directly, such as through muscles, other neurons may make contact with the glands that can release hormones into the body. In this way, the nervous system can influence parts of the body outside of itself.

Neural Change in Learning

Although communication between neurons occurs at the synapse, how do these connections get altered as new things about the world are encoded into memory? These connections must change in some way. One way that this is done is through a process known as **long-term potentiation**, or **LTP** (Bliss & Collingridge, 1993; Bliss & Lomo, 1973; Gustafsson & Wigstrom, 1988), often investigated using cells from the hippocampus (see later). LTP strengthens the connections between neu rons by altering the ease with which postsynaptic neurons will fire. The majority of the change that strengthens a connection between neurons is occurring at the dendrites. Along the cell membrane of a dendrite, there is an increase in the number of receptor cites for the neurotransmitters, as well as the growth of dendritic spines, although there may be some changes in the presynaptic neuron's axon as well (Emptage, Reid, Fine, & Bliss, 2003). As a result, more neurotransmitters can bind to the post-synaptic cell membrane, making it easier to reach the level of depolarization needed to cause the neuron to create an action potential. Note that there is also an analogous process called **long-term depression**, or **LTD**, which weakens connections between neurons, which can also be important for learning (e.g., Duffy, Labrie, & Roder, 2008).

Often, LTP can last for days or weeks, but it eventually dissipates. Thus, LTP is the type of neural change that occurs in memory formation early on, but another process will be needed for information to be stored more permanently in other parts of the brain. An important point to keep in mind is that LTP is not observed in the living brain but is a phenomenon observed by sending rapid pulse trains to sets of neurons in petri dishes (Eichenbaum, 2002).

Stop and Review

The fundamental building blocks of the nervous system are neurons. Memory is an emergent property of collections of neurons working together. Understanding how neurons work and communicate provides a better understanding of how memory works. Neurons have important features, such as dendrites and axons that are involved in neural communication. The electrical component of neural communication is captured in the action potential, and the chemical component by the neurotransmitters. Neurons form memories by altering their connections to one another.

CORTICAL LOBES

Up to this point, we have been talking about low-level processes. Now we are going to jump up to larger levels of neural organization. There are many structures that make up the brain. Those that have a more direct involvement in memory can be classified into two broad categories: (1) the various lobes of the cortex, and (2) the subcortical structures, which are parts of the brain that lie beneath the cerebral cortex.

The phylogenetically newest, and most prominent, part of the brain is the cerebral cortex. This is the wrinkly part that sits on top and is what most people think of when they picture a brain. The wrinkled appearance is because there is so much surface area crammed into such a small volume. The brains of other animals, such as reptiles and amphibians, may be smooth in their entirety. In contrast, our brains are more powerful, because we have many more neurons. However, this increase in brain size brings with it an increase in head size. If the head becomes too large, then other problems arise, such as ease of birth, and supporting and controlling such a large structure on the neck.

To keep the head reasonably small, while increasing the number of neurons, the cortex has become folded and wrinkled. If you removed a person's cortex and lay it flat, you would see that it is very large. The average adult's cortex covers about 1,800 square cm (about two square feet) and is 2 to 3 mm thick. The wrinkling preserves the size of the surface area while reducing the volume occupied. An analogy is trying to get a sheet of paper into a cup. The paper won't go in lying flat. But, if you wrinkle it up and stuff it in, you've taken a large surface area and enclosed it in a small volume.

The cortex is divided into a number of major regions. First, there are the two hemispheres, a left and a right hemisphere. Some memory functions are more dependent on one hemisphere than the other. This dominance of one hemisphere over the other is called **laterality**. For now, note that the left hemisphere is generally regarded as being better at analytic processing, such as language and math, and the right hemisphere is better at holistic processing, such as spatial or music processing.

Each hemisphere is divided into four subsections called lobes (see Figure 2.3). Each lobe is associated with different functions. At the back of the brain is the **occipital lobe**, which is involved in visual processing. In front of the occipital lobe, on the top of the brain and just behind the central fissure, is the **parietal lobe**. This is responsible for sensory processing from throughout the body, as well as spatial processing (e.g., knowing where something is). In front of the occipital lobe and below the parietal lobe, under the lateral fissure, is the **temporal lobe**. This is responsible for auditory processing and retaining knowledge about the identity of things in the world. Finally, at the front of the brain, in front of the central fissure and above the lateral fissure, is the **frontal lobe**. This is the evolutionarily most recently developed part of the cortex and is involved in the control of action, emotion, and thought. The frontal lobes help a person select those memories that are most relevant on a given occasion. They also coordinate various types of information into a coherent memory trace. The names of the lobes correspond to the bones of the skull that overlay them.

TRY IT OUT

One issue raised in this chapter is the idea of hemispheric lateralization for different mental processes. This lateralization includes memory. In addition to processing different kinds of information, keep in mind that the hemispheres are primarily responsible for controlling the opposite sides of the body. This is called a *contralateral connection*. One manifestation of this is handedness. Most of us are right-handed, but some of us are left-handed. Our handedness can influence how we process information from memory, including whether we like something or not, and how we respond to and process information (Casasanto & Jasmin, 2010).

For this task, first create a list of 20 or so product types, such as detergent, cars, breakfast cereals, and so on. What you should do for each person is have them give a description of one version of the product that they like and another for one that they do not like. Be sure to tell people that they can gesture with their hands if they like. What you will need to do is keep track of which hand a person is gesturing with when they are describing products they like and dislike. You should have four categories of responses: (1) left hand mostly, (2) right hand mostly, (3) both equally, and (4) neither. While the person is talking, keep track of which hand is used to gesture as they describe the products. After you have collected your data, ask each person whether they are right-handed or left-handed.

After you have finished, average the number of times each person used one of the four gesturing categories when describing products that they felt positively and negatively about. Be sure to classify the responses as being dominant or nondominant hand so that you can collapse the data across both right- and left-handers. When you look at your data, what you may find is that which hand people used to gesture with varies with whether they liked a product. It has been found is that people are more likely to gesture with their dominant hand (right for right-handers, left for left-handers) when making positive statements about things they like and are more likely to use their nondominant hand for negative statements about things they dislike.

To help you localize different parts of the cortex, throughout the text there will be both verbal descriptions of the location and a number that refers to the **Brodmann area** (e.g., BA 20). This is a reference to a particular part of the cortex that has been identified on a Brodmann atlas. Copies of the Brodmann atlas are provided in the end pages of this book for your easy reference.

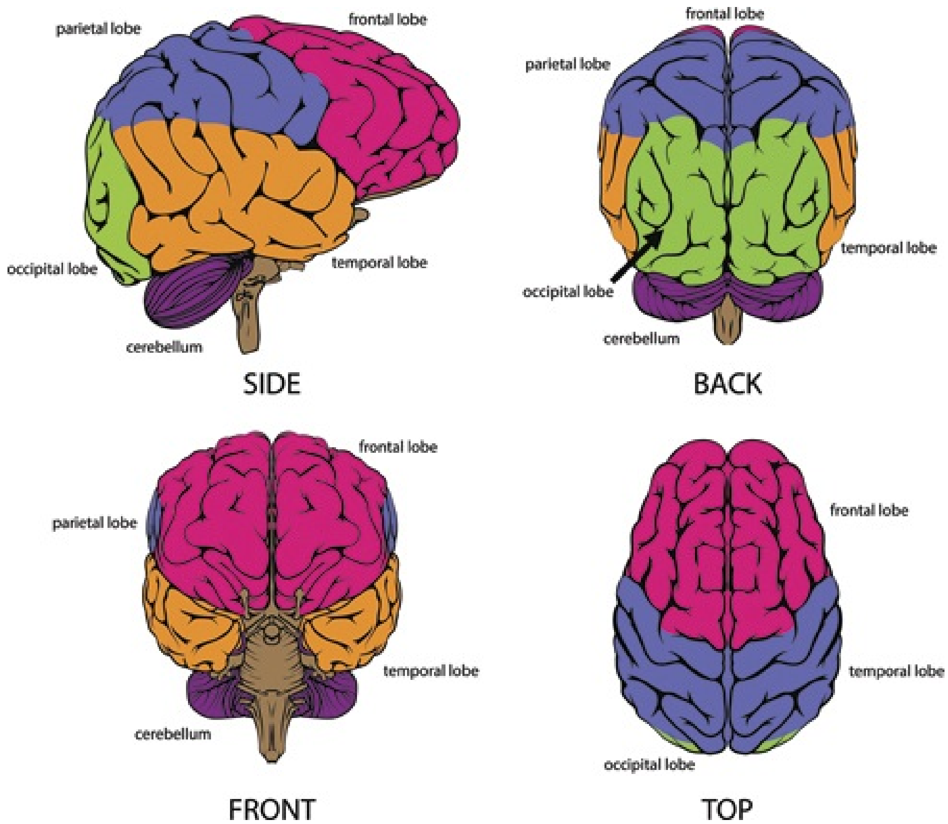

FIGURE 2.3 *The Organization of the Cortical Lobes*

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Occipital Lobes

The occipital lobes are involved more in perception than memory. However, there are some aspects that can be interpreted as memory. The occipital lobes detect features in the environment (Hubel & Wiesel, 1965), but the sensitivity to these features is based on experiences with the world. For example, if kittens are reared in an environment in which they only see horizontal lines, when they are adults they will walk into a table leg because they cannot see vertical lines. They lack the feature detectors for vertical objects (Blakemore & Cooper, 1970). This suggests that our perceptual experiences are based on mental representations for the components of the visual world. These components are then stored in the perceptual system over the long term. As such, they can be considered a form of very long-term memory representations for the bits and pieces that make up the world.

Parietal Lobes

The parietal lobes are less often thought of as being involved in memory than the temporal and frontal lobes, but they are used in a wide range of circumstances. For example, working memory processes for visual memory or the spatial manipulation of information (see Chapter 8) involve the parietal lobes (Mishkin & Appenzeller, 1987). This would include doing a task that involves mental imagery, such as scanning a mental image. Animals that have had their parietal lobes surgically removed have trouble remembering spatial relations.

Temporal Lobes

The lobe most closely associated with memory are the temporal lobes. This is not surprising as they surround the hippocampus, which, as you will soon see, is one of the more important structures for memory. The part of the temporal lobe that is often studied with regard to memory is directly adjacent to or surrounding the hippocampus. The area adjacent to the hippocampus is often referred to as the medial temporal lobe. The temporal lobes are where many of our long-term memories for different types of information may be stored. Damage to this part of the brain often results in some memory loss. This part may be involved in remembering events from one's own life, something called autobiographical memory (see Chapter 12). It may also be the source of remembering ideas related to concepts you are pondering at the time, for example having the idea "wood" become more accessible after hearing the word "lumber." This is a memory process called priming (see Chapter 3).

Frontal Lobes

The frontal lobes are also important to memory. Again, they are involved in the coordination of information, so they are critical for working memory (see Chapter 5). Sometimes we have situations where information becomes separated, such as when we recall something but cannot remember where we know it from. For example, did you hear about that secret from your friend Jordan or from Riley? Alternatively, we may remember that someone told us *something*, but we cannot remember what it was. Knowledge of the information content, as well as knowing where it came from, must be put together using a process of source monitoring (see Chapter 13). The frontal lobes are also involved in remembering what we need to do in the future, something called prospective memory (see Chapter 7). A failure to remember to tell your roommate that his mother called may be due to a problem with the memory processes controlled by the frontal lobe.

The Default Mode Network

The various hemispheres and lobes of the cortex are involved in different mental processes in and of themselves, but they also work together in various ways. One example of different brain regions working together is the **default mode network**, or **DMN** (Buckner, Andrews-Hanna, & Schacter, 2008). The DMN is a collection of brain structures whose activity is highly correlated. The DMN is more active when a person does not have attention strongly engaged in some activity. That is, the activation of the DMN is negatively correlated with activity in of various attention networks in the brain (Andrews-Hanna, 2012). In some sense, this network in the brain that is more active by default when people are colloquially thinking about “nothing in particular,” such as when they are daydreaming, mind-wandering, autobiographically remembering, or perhaps engaging in episodic future thinking about their own lives or people they know. This network is also active when a person is watching a television show or a film (Hasson, Furman, Clark, Dudai, & Davachi, 2008; Lerner, Honey, Silbert, & Hasson, 2011; Regev, Honey, Simony, & Hasson, 2013) and so may be involved in basic comprehension.

The DMN is made up of a number of structures, including parts of the parietal lobe, such as the posterior cingulate cortex (BAs 23 and 31), the angular gyrus (BA 39), and the precuneus (BA 7), parts of the frontal lobe, such as the dorsomedial and medial prefrontal cortices (BA 11), and parts of the temporal lobe, including its lateral portions and the anterior pole, as well as parts of the hippocampal complex such as the hippocampus, para hippocampus, and retrosplenial cortices (see the next section) (Andrews-Hanna, Smallwood, & Spreng, 2014). Keep in mind that the DMN is an example of one collection of structures working together. There are others.

Stop and Review

The brain is made up of specialized substructures. The most prominent of these are the two hemispheres. Each hemisphere is divided into four lobes. The temporal lobe plays a prominent role in memory, along with the frontal and parietal lobes, whereas the occipital lobe is the least involved. Different parts of the cortex are involved in specialized processes. They coordinate with one another to accomplish various tasks, as with the default mode network.

SUBCORTICAL STRUCTURES

In addition to the cortical lobes, there are a number of subcortical structures that are centrally involved in memory. The most important of these is the hippocampus. In addition, there is also some coverage of the amygdala, basal ganglia, and diencephalon.

Hippocampus

The subcortical structure that gets the most attention in memory research is the **hippo campus** (see Figure 2.4). This is a seahorse-shaped structure (hence the name). The hippocampus, as well as the related surrounding complex of areas, is important for conscious memories of events (Mishkin & Appenzeller, 1987). Much of the research on long-term potentiation has been done by studying neurons from the hippocampus. While it is strongly associated with LTP, and thus may be able to retain information for up to several weeks, it does not appear to be the location where very long-term declarative memories are actually stored. Instead, it may be involved in helping to encode these memory traces into other parts of the cortex, where they are held for longer periods of time (see the later section on consolidation) (O'Reilly & Rudy, 2001). The hippocampus may serve as a waystation for knowledge on the journey to permanent encoding (if it makes it that far).

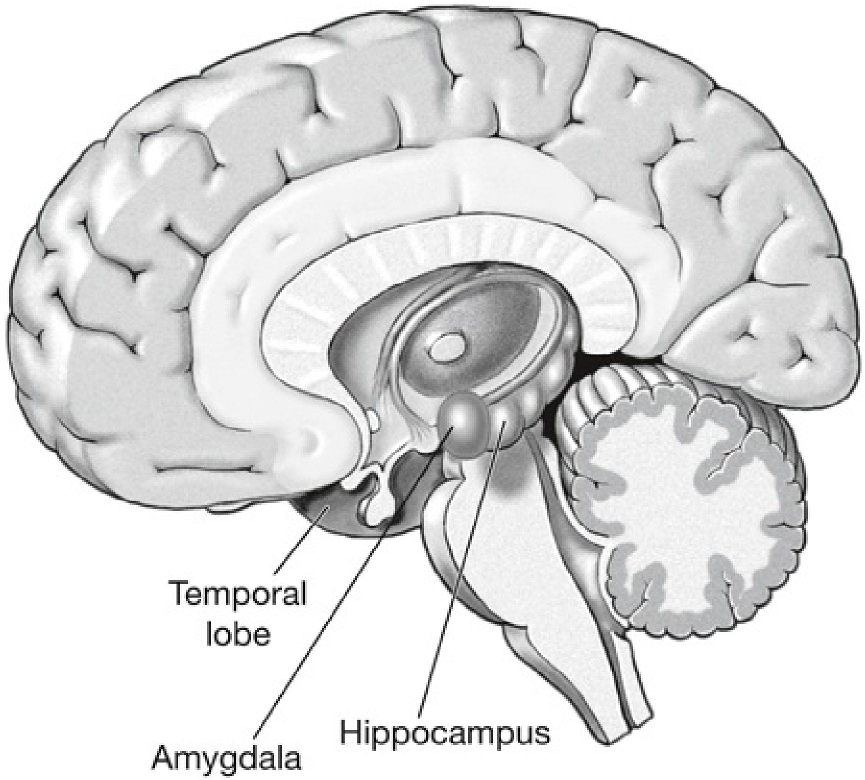

FIGURE 2.4 *The Hippocampus and the Amygdala*

The hippocampus itself, like many brain structures, is divided into a number of subregions, as shown in Figure 2.5, and is surrounded by important cortical areas, which are collectively known as the hippocampal complex. In terms of the hippocampus itself, it is composed of the *dentate gyrus*, regions *CA1*, *CA2*, *CA3*, and *CA4* (with areas *CA1* and *CA3* being more implicated in memory processing), and the *subiculum*.

Outside the hippocampus proper, there are a number of associated areas of concern, as shown in Figure 2.6. First, for processing spatial information there is the *parahippocampal cortex*, which is posterior (behind) and inferior to (below) the hippocampus. Next, for processing object information, there is the *perirhinal cortex*, which is inferior to the hippocampus and anterior to (in front of) the parahippocampal cortex (BA 35). Finally, there is the *entorhinal cortex* (BAs 28 and 34), which is anterior to and inferior of the hippocampus. The entorhinal cortex takes information from the parahippocampal and perirhinal cortices and passes it along to the hippocampus itself.

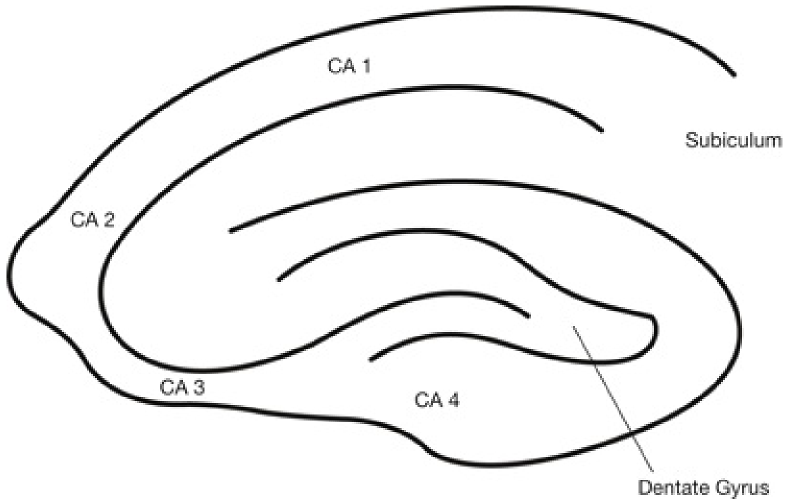

FIGURE 2.5 *The Structure of the Hippocampus*

In addition to processing what and where objects are, their importance or emotional value is signaled by processes in the orbitofrontal cortex of the frontal lobe (BA 11) and in the amygdala (see below). These signals are processed through the perirhinal and entorhinal cortices. Thus, across the hippocampus-related brain regions, an array of connections allows the hippocampus to integrate and bind information about the spatial-temporal context, objects, and their value.

For the hippocampus itself, by and large, the dentate gyrus and area CA3 receive inputs from the medial entorhinal cortex. Moreover, the dentate gyrus also sends signals to areas CA3. In comparison, area CA1 receives different inputs from the lateral entorhinal cortex and passes this information on to the subiculum. Area CA1 also receives inputs from area CA3. The subiculum sends its processes on to the entorhinal cortex. Some fibers from the hippocampus also travel to the *fornix*, the *mammillary bodies*, and the *thalamus*.

A great deal of research on the hippocampus is focused on its role in the formation and storage of new memories. Damage to the hippocampus can lead to severe declarative memory deficits (Mahut, Zola-Morgan, & Moss, 1982), such as antero-grade amnesia (see Chapter 18). That said, it also may be involved in the retrieval and the replaying or re-experiencing of prior events (Karlsson & Frank, 2009), and the imagining of future event possibilities (Addis, Wong, & Schacter, 2007; Hassabis, Kumaran, Vann, & Maguire, 2007).

In addition to long-term memory, the hippocampus and associated structures are involved in processing spatial information. For example, place cells (which are active when an organism is in a particular location) are found in the hippocampus (O'Keefe & Dostrovsky, 1971), grid cells are found in the entorhinal cortex (Hafting, Fyhn, Molden, Moser, & Moser, 2005), and boundary cells are found in the subiculum and entorhinal cortex (Solstad, Boccara, Kropff, Moser, & Moser, 2008). Thus, hippocampal areas are important for encoding and processing context. There is also some evidence for hippocampal time cells that track when events occur (Howard & Eichenbaum, 2013). Thus, the hippocampus is important for processing the spatial-temporal framework within which episodic memory events occur.

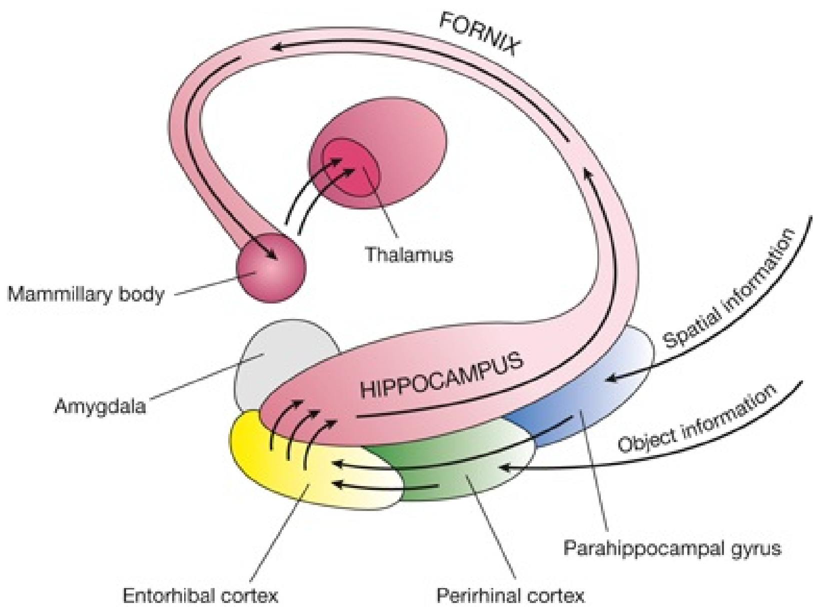

FIGURE 2.6 *The Connections of the Hippocampus to the Cortex*

Overall, the hippocampus is specialized for processing and binding conjunctions of stimuli that appear together in the environment. It is well designed for the rapid encoding and binding of episode-specific conjunctions—that is, whatever is co-occurring at the moment. This includes the spatial and temporal contexts, as well as the objects within the current event. The hippocampus does this by processes of pattern separation (segmenting experience) and completing missing elements from general world knowledge (Behrendt, 2013). That is, the hippocampus binds together information from a variety of sources to create integrated memories of individual scenes or events (Maguire & Mullally, 2013). There is evidence that when an event is complete there is an increase in hippocampal activity at event boundaries, as it closes up one event and opens up a new one (Ben-Yakov, Eshel, & Dudai, 2013).

Other Subcortical Structures

Another important memory structure is the amygdala (see Figure 2.4). The **amygdala** is an almond-shaped structure (hence the name) located at the lower, anterior part of the hippocampus. The amygdala is involved in processing emotional aspects of memories (Davis, 1997; Mishkin & Appenzeller, 1987). For example, if there is an emotional reaction to an event, that reaction would be encoded into the memory trace via the amygdala.

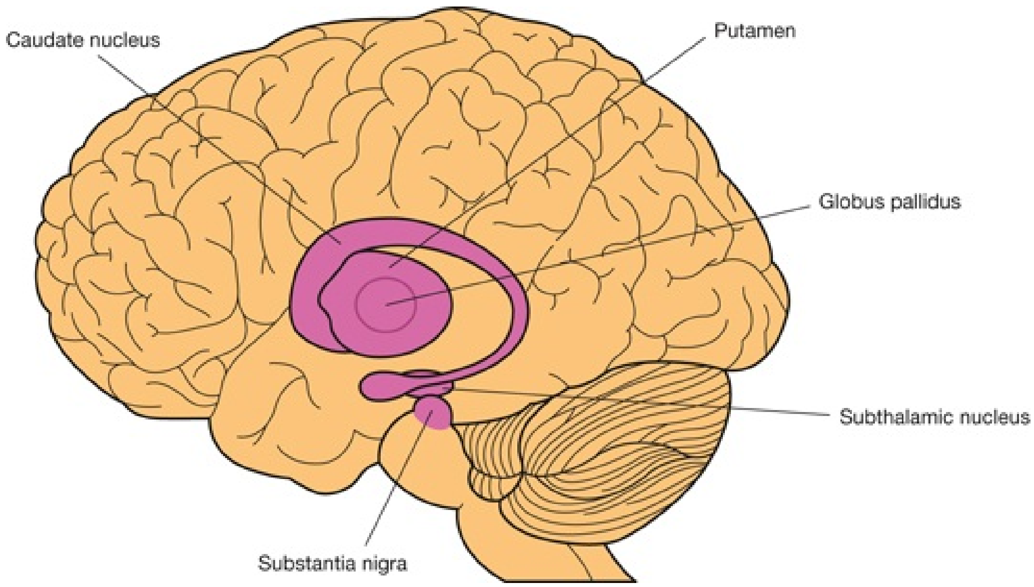

FIGURE 2.7 *Basal Ganglia Structures*

The **basal ganglia** are a collection of subcortical structures (including the caudate nucleus, the putamen, globus pallidus, and the subthalamic nucleus) located above and around the thalamus (see Figure 2.7). These structures are important for motor memory—that is, the control of the voluntary muscle groups. The basal ganglia are implicated in memory for habits and motor skills, such as riding a bicycle. A related set of findings is observed with the **cerebellum**. This is a phylogenetically old structure located at the back of the brain (see Figure 2.3). Like the cortex, it has a convoluted surface structure, so it looks like a little brain underneath the larger one (and hence its name). The cerebellum is associated with complex motor control and coordination. As such, it is used in memory for procedural skills that involve the complex coordination and control of the muscles, such as walking. This is a more primitive form of memory, but very important nonetheless.

The **diencephalon**, including the **thalamus** and **hypothalamus**, serves as a routing station for signals from different parts of the brain. It is also involved in memory for conscious, factual knowledge. It has been suggested that the diencephalon is important in processing information about the temporal sequence of events. More indirectly, the diencephalon is involved in controlling the neurotransmitters that are present in the nervous system at any given time, and so it has a roundabout influence on memory.

Stop and Review

The most important subcortical structure for memory is the hippocampus and its related brain structures. Anterior hippocampal connections are involved more in the processing of objects and identities, whereas the posterior hippocampal connections are involved more in the processing of spatial-temporal contexts. There are also inputs relating to the emotional and evaluative components of processing. Other important subcortical structures for memory include the amygdala, which is involved in processing emotion, the cerebellum and basal ganglia, which are involved in motor memories, and the diencephalon, which is involved in the routing and coordinating of information.

NEUROLOGICAL MEASURES

One of the most exciting areas of research is the development of methods and tools that allow us to look at how the brain works to encode, store, and retrieve memories. Some of these methods are described here. In this section we look at measures of brain structure, as well as functions based on cortical electrical activity and blood flow.

Structural Measures

Although it is important to know the various functions that operate in the brain, it also helps to know its structure, especially of a specific person or group of people. Sometimes clues to patterns in the way people think can be gained by understanding how their brains might be physically different from the norm. One thing to keep in mind about the brain is that its physical structure is not uniform; it differs from person to person, in much the same way that each person's face is unique. The best way to view the physical structure of a brain is to remove it from the skull (after death, of course). However, this approach has its limits. Another way is to open up the skull of a living person and examine the brain, which can happen during surgery.

Apart from death and brain surgery, there are other ways to examine the structure of the living brain. One way is to take a series of X-rays of the skull, each of them taking a different “slice” of the head, and then examine the brain structures revealed. This is known as a **computer-assisted tomography** scan, or **CT** scan (also known as a CAT scan). An example of a CT scan of the right and left hemispheres of the brain is shown in Figure 2.8. CT scans show the structure of a living brain and can reveal things such as the location of a tumor, damage from a stroke, or just the general condition of a brain.

A neuroimaging technique that has gained popularity is **magnetic resonance imaging**, or **MRI** (sometimes called nuclear magnetic resonance imaging). MRI works with the resonant frequencies of different molecules in the brain. First, a person is placed in a strong, controlled magnetic field. This is the magnetic part of MRI. This magnetic field affects the spin of all of the atoms of a certain type in the body, such as all of the hydrogen atoms, causing the protons in those atoms to line up along a specific axis, with about half oriented in each direction along that axis. After this, a radio frequency pulse is passed through the body. This pulse causes unmatched protons to spin in a different direction at a specific frequency. Con-currently, a set of gradient magnets are cycled on and off, which alter the primary magnetic field, allowing images or slices of the brain to be acquired. When this pulsing stops, the hydrogen atoms go back to their normal state and release the energy absorbed from the pulses. This is the resonance in MRI. This energy is detected by the coils in the machine and sent to a computer for analysis. The computer then interprets the data and creates the MRI image.

FIGURE 2.8 *A CT Scan of the Brain*

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An MRI brain scan is shown in Figure 2.9. Typically, the density of water molecules, which contain hydrogen, is used to determine structure. The density of hydrogen atoms varies as a function of whether a particular region contains unmyelinated neurons, myelinated axons, cerebral spinal fluid, and so on. An advantage of MRI is that it is not necessary to inject a chemical into the body, as with PET scans (see later), or use harmful radiation, as with CT scans. Perhaps the biggest advantage of MRI scans is their clarity. These images are of a higher quality than those from a CT scan.

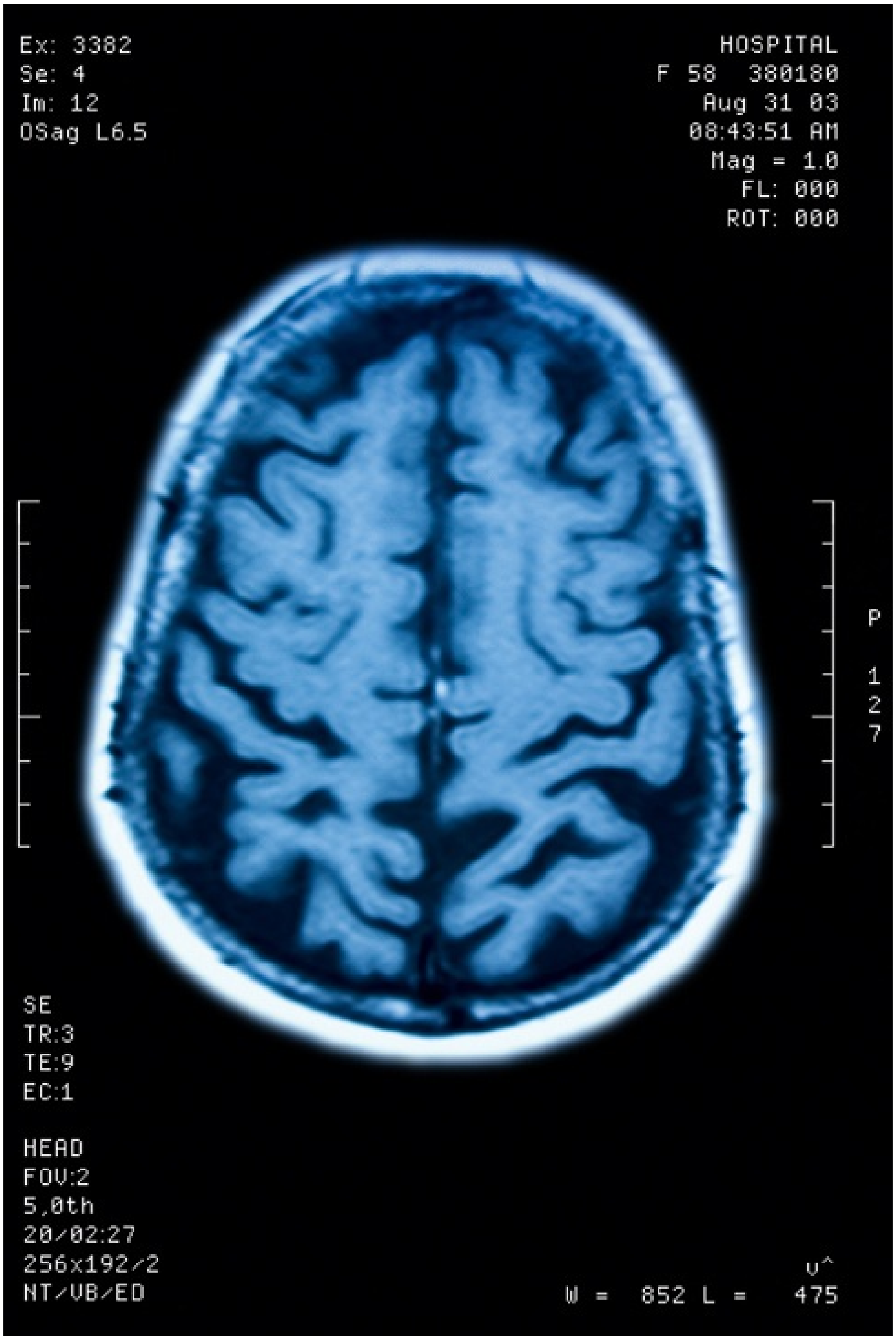

FIGURE 2.9 *An MRI Scan of the Brain*

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Electrical Measures

This section examines measures of electrical activity generated by action potentials in the brain. Be sure to read the Study in Depth box below to learn about an early attempt to use electrical stimulation to recover otherwise lost memories by Wilder Penfield in the 1950s.

STUDY IN DEPTH

Wilder Penfield (1891–1976) was a Canadian neurosurgeon held in high regard for his mapping of the sensory and motor homunculi in the cortex. He did this by probing people's brains with a mild electrical charge during surgery. These people had some intractable condition, so parts of the cortex were removed in an attempt at a cure (with a reasonable level of success). While the patient was awake, a section of skull was removed. This was done so that the patient could report what effects the stimulations had. This allowed Penfield to identify those parts of the brain that were critically important. Although many functions rely on similar areas of different people's brains, there is some variability. While probing, Penfield would sometimes get interesting reports when a portion of the temporal lobe was probed. These reports were as if people were re-experiencing memories of their lives. Here is one example.

> The patient then said something about "street corner." The surgeon asked him, "Where?" and he replied "South Bend, Indiana, corner of Jacob and Washington." When asked to explain, he said he seemed to be looking at himself—at a younger age.
>
> (Penfield, 1955, p. 52)

Penfield reported that he had several responses of this nature from different patients. He interpreted these reports as memories. What was striking to Penfield was that they were not the events that a person typically recalls from their lives but were rather boring and mundane memories. The vividness of these reports and their everyday quality led Penfield to suggest that the brain records the stream of consciousness throughout a lifetime. Long-term memory acts like a videorecorder. The electrical probe that he had applied allowed people to remember and replay otherwise forgotten aspects of their lives.

Although this is striking, there are some caveats, as outlined by Loftus and Loftus (1980). First, it is unclear to what extent the reports were actually memories or were experiences generated at the time. These "memories" may be created in much the same way that dreams are. According to the activation-synthesis theory (Hobson, 1988), during sleep the cortex is stimulated with random electrical pulses. Because the brain does not like randomness, it imposes structure on the information it is getting. To do this, it uses readily available information that is reasonably close to the stimulation. This is information in long-term memory. Penfield's reports could be of the same quality. His patients were getting random stimulation and their brains were doing the best to make sense of this random input with whatever knowledge was available in memory. If so, then these reports were mental constructs created at the time from a combination of random inputs from the probe along with information that was stored in memory.

Another problem is that there were very few of these reports. Of the 1,132 of Penfield's patients, only 40 (3.5%) had what he interpreted as memories, and most of these were not full-blown reports. Twenty-four had auditory experiences (e.g., hearing voices or music), 19 had visual experiences (seeing familiar people or objects), and only 12 gave what appeared to be complete memory reports. Thus, there is very little evidence to work with.

Some of these reports could not possibly have been re-experiences of past events. For example, in the report just given the person states that he can see himself standing on a street corner. If memories of experiences were faithfully recorded, this could not happen. You can't look at yourself from a distance without a mirror or a TV camera, for example.

The most direct use of electrical component of neural communication to assess memory is **single-cell recording**. In this method, an electrode is used to probe an individual living cell, somewhere in the nervous system. The researcher is then able to determine when the cell fires. Each time the electrical charge flows down the axon, it is recorded (this technique may also pick up activity of other neurons in the proximity of the probe). The experimenter then has the subject engage in the task of interest, watching to see how the firing pattern of that individual cell changes.

Obviously this is a very micro level of analysis. Information is only gathered about the operation of one cell in a brain made up of billions of neurons. Nevertheless, this technique can provide information about how different cells in the brain are processing different types of information. Also, this technique is very invasive, so it is typically limited to animal research. That said, there are studies emerging that use information from single-cell recording in humans who have had these electrodes embedded in the medial temporal lobe or hippocampus for clinical reasons (e.g., Suthana & Fried, 2012).

While single-cell recording provides information about what is going on in one cell, other measures provide information about large groups of cells and are noninvasive, so they can be used with ordinary people doing more complex tasks, such as remembering a poem. For this procedure, electrodes are attached to a person's scalp to record the electrical activity in the underlying part of the brain. These recordings are called ***e*lectro *e*ncephalo *g*raphy**, or **EEG** waves. Often there are several electrodes at regularly spaced and predetermined locations over the skull to help localize the recorded activity.

EEG waves can be used to measure **event-related potentials**, or **ERPs**. An ERP is a regular change in the pattern of electrical energy measured as a function of the particular task or event that the person is thinking about (Coles, Gratton, & Fabiani, 1990). The memory researcher has a person engage in various tasks at predetermined points in time. These are the "events" of event-related potentials. Then the researcher looks at the EEG waves that were recorded at that time relative to when the events occurred. These electrical "potentials" in the EEG waves are what are "related" to the earlier "events"—hence the name *event-related potentials*.

If you've ever seen an EEG wave, it looks like a random bunch of squiggles. And for each trial of an ERP study, this is largely what it is. Keep in mind that the brain is actively doing many things other than the particular task at hand, so there is a lot of electrical activity from these processes. To get a clearer idea of what is going on, the researcher needs to average the electrical potentials across a large number of trials. This averaging process washes out much of the noise, leaving a clearer signal. As more trials are averaged together, the ERP wave becomes more pronounced. This ERP signature is often a relatively large wave of positive or negative electrical charge in a region of the brain occurring at a particular point in time after the target event. The ERP can then be related to theories of memory process. The ERP wave suggests that some kind of mental work is taking place. A difference between two waves corresponding to two different conditions in the study corresponds to different types of mental processes.

A big advantage of ERPs is temporal resolution—that is, knowing when things happen in the brain. Recordings can be made at 1 ms time slices. Thus, it is clear when certain processes are kicking in or when different regions of the brain are involved. People often talk about ERPs in terms of interesting components in the waveform and the nature of these components. For example, people might talk about a P300 wave, which refers to an electrically positive wave occurring about 300 ms after the beginning of an event. An N400 wave refers to a negative wave occurring about 400 ms after the beginning of an event (Bentin, 1989).

There are some disadvantages to ERPs. One is that the spatial resolution —*where* things happen in the brain—is poor. One can get a general idea about what part of the brain is involved but determining a precise location is difficult. This is further complicated by the fact that there is a lot of "stuff" between the electrodes and the brain activity they are recording—skin, blood vessels, meninges, and bone. In some ways, using EEG recordings to figure out what is going on in the brain is like trying to figure out what is going on in a factory by listening through the wall.

While ERPs provide information about the level of positive or negative electrical charge at a point in time, there is other information that can be extracted from EEG signals. The nervous system has a tendency to have various oscillators throughout it. That is, groups of cells tend to fire together. This is called synchronization, and when this increases after an event it is called **event-related synchronization**, or **ERS**. When a person is at rest, synchronization is stable. However, when a person is engaged in a mental activity there may be a desynchronization. This is called **event-related desynchronization**, or **ERD**. Furthermore, these oscillations occur at different frequency bands, depending on how fast the oscillations are. One way of dividing up the frequency bands is to have different regions separated by about 2 Hz each, using a person's based frequency as a reference point, defining the delta band as –8 to –6 Hz, the theta band as –6 to –4 Hz, the lower 1 alpha as –4 to –2 Hz, the lower 2 alpha as –2 to 0 Hz, and the upper alpha as 0 to +2 Hz (Dopplemayr, Klimesch, Pachinger & Ripper, 1998). Changes in any of these bands can vary as a function of the memory task.

ERD patterns are related to memory performance. For example, during effective memory processing there is decreased alpha synchronization and increased theta synchronization (Klimesch, 1999). Essentially, the resting alpha synchronization is disrupted by activity of a particular type. The theta synchronization is associated with increased activity in the hippocampus and surrounding structures. Moreover, alpha and theta band power have been related to activation and inhibitory processes in memory (Klimesch, 2012). Finally, the distinction between episodic and semantic memory is supported by ERD work showing greater upper alpha desynchronization for semantic memory, and increased theta band synchronization for episodic encoding (Klimesch, 1999).

Another method for exploiting the electrical aspect of brain processing is ***t*ranscranial *m*agnetic *s*timulation** (**TMS**). In TMS, a magnetic field is used to alter the electrical charges of the neurons in a targeted part of the brain, thereby exciting those neurons. This either further enhances the processing of those cells or takes out that region as a kind of temporary lesion in a normal person's brain.

An advantage of TMS is that it allows a memory researcher to explore how different parts of the brain are used in different tasks by selectively affecting neurons in various areas of the brain of an otherwise normal person. As one example of the use of TMS to study memory, Kirschen, Davis-Ratner, Jerde, Schraedley-Desmond and Desmond (2006) used TMS to disrupt the phonological similarity effect in working memory (see Chapter 5). As another example, Smirni, Turriziani, Mangano, Cipolotti, and Oliveri (2015) used TMS over the right dorsolateral prefrontal cortex (but not the left) to enhance memory for faces.

Another development in neuroimaging is **magnetoencephalography**, or **MEG**, which uses magnetic fields to measure cortical electrical activity. Many parts of the brain are always active, doing lots of different things at any one time. To get an idea of what part of the brain is involved in a process measured in a MEG scan, the **subtractive method** is used. With the subtractive method, scans are taken both when the person is doing the mental activity of interest as well as a control condition in which the person not thinking about anything in particular. The brain activity of the control condition is subtracted from the activity recorded during the process of interest. The difference in activity tells the researchers which parts of the brain are more or less active for that type of processing. This subtractive method is also used with other types of neuroimaging, such as PET and fMRI scans (see the following section).

Overall, researchers can use MEG technology to pinpoint which parts of the brain may be active for various memory tasks. MEG scans have better spatial resolution than EEG and have a good temporal resolution, of about 10 ms. This is not as good as ERPs but still respectable. As one example of using MEG to study memory, Kim, Kim, and Chung (2008) tested recognition memory for words. The MEG scans revealed that medial temporal lobes are more involved when there is a delay prior to recognition compared to when it is more immediate.

Blood Flow Measures

Not all neuropsychological methods use electrical impulses. Some involve measures of cerebral blood flow. Collections of neurons that are working harder need more nutrients to be replenished and keep going. As a result, blood flow to those areas increases to compensate for this. The discovery of a relationship between blood flow and neural activity was somewhat serendipitous (Posner & Raichle, 1994). In the early twentieth century, Walter K. had an abnormality in the blood vessels in his brain. There was a large clump of vessels over his occipital lobes. Walter complained of a constant humming in his ears, which was the blood rushing through these vessels. He noticed that the humming decreased when his eyes were closed and increased when his eyes were open. The increased activity in the occipital lobes was associated with increased blood flow. Here, we look at two measures that use blood flow to assess brain activity.

For ***p*ositron *e*mission *t*omography**, or **PET**, people are injected with a radioactive isotope of oxygen called oxygen-15 or 15O. This isotope decays to 16O, which is reasonably stable. The level of radioactivity is very low and short-lived (it has a half-life of just over two minutes), so there is little harm to the body. Once the isotope is in the bloodstream, the person is placed in a scanner that measures the levels of the isotope in the brain. Recording levels in control conditions are compared with experimental conditions where the person is engaging in the type of thought that is of interest for the study. Depending on the task, different parts of the brain are more or less active. A sample PET scan image is shown in Figure 2.10. These different levels of activity can be used to help determine which parts of the brain are being used.

Compared to ERPs, the spatial resolution in PET scans is much better. However, with PET it takes a long time for a good image to be generated, typically no faster than 20 seconds. How many different thoughts you could have if you were lying on your back in a scanner for 20 seconds? Thus, while the spatial resolution is better, the temporal resolution is relatively poor. So, we can determine *where* something is occurring in the brain but not *when*.

The MRI technology discussed earlier also has an advantage over CT scans in that it can be adapted to look at function as well as structure. This is called **functional MRI**, or **fMRI**. fMRI uses the detection of oxygen atoms as a measure of mental activity. The density of oxygen molecules is associated with the operation of neural assemblies and the flow of blood to fortify those cells. After all, the delivery of oxygen is one of the primary purposes of the bloodstream. An fMRI scan has an advantage over PET because no injection is required and the images can be taken in a shorter period of time, in the order of a few seconds. Still, fMRI scans cannot match the temporal accuracy of ERP measurements.

At this point a number of neuroimaging methods have been mentioned. Each of these is used to take a picture of either the structure of the brain or the neurological operations that occur. There can be no question that such methods provide unique, intriguing, and valuable insights into the human experience. So, why not use such methods exclusively? Well, it should be kept in mind that these methods provide only neurological information. They do not provide much information about the content of thoughts and memories. To know *what* a person is remembering, we still need behavioral methods.

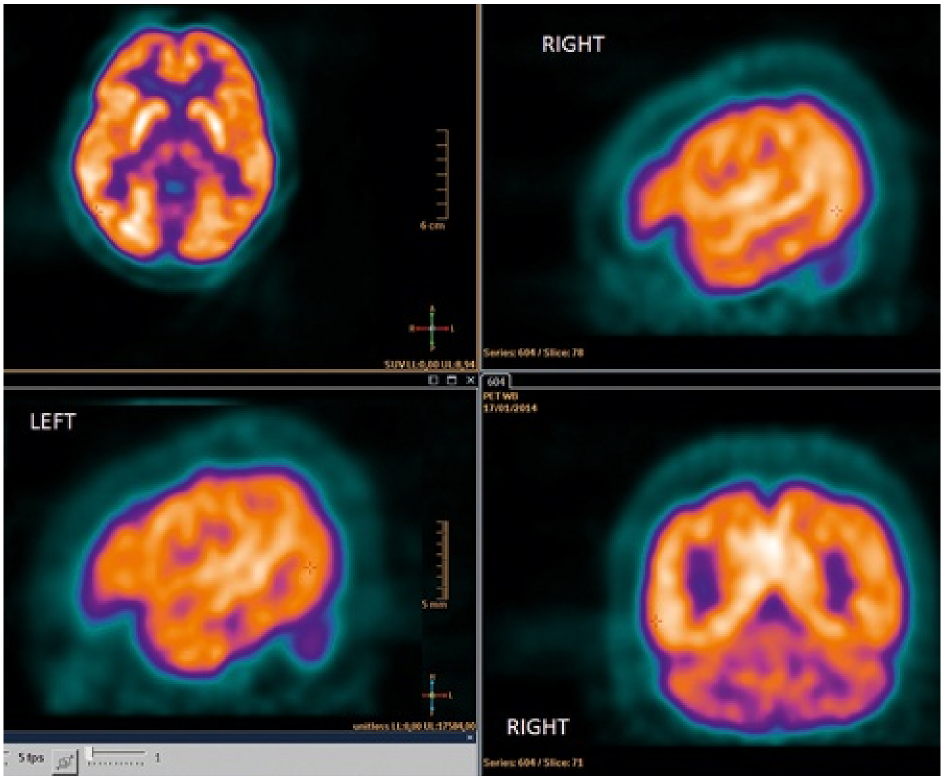

FIGURE 2.10 *A PET Scan Image*

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Altered Brains

Another source of insight into neurological underpinnings of memory comes from **case studies** of people who have suffered some damage or lesion to the brain. This might be from an external event, such as a car accident or a gunshot; an internal event, such as a stroke or a virus; or, in rare cases, from surgery. By examining the memories that are affected following damage to a specific part of the brain, some inferences can be made about what role that structure plays. For example, if the damage leads a person to be able to remember very little in the short term, it suggests that short-term memory uses this structure. Because of their very nature, it is not unusual for a single case to be studied in depth to help understand what happened, what went wrong, and what techniques can be used to improve the situation.

Although brain lesions provide valuable insights, they are imperfect. First, seldom is there a pure lesion, with one structure being affected and the other structures remaining unharmed. Lesions are often messy and affect a number of structures. This is true for both accidents and diseases affecting humans, as well as animal studies in which lesions are intentionally made surgically. Another problem with lesion studies is that there are never two cases of people with identical lesions. Thus, it cannot be determined whether the consequences of the damage are unique to that person or are a generalizable consequence. Finally, lesions are haphazard both in terms of where and when they occur. They do not afford the sort of control one would have in a systematic study. Thus, while important and valuable information can be gained from case studies, there are clear limitations to the conclusions that can be drawn.

Studies of **special populations** of people who have a neurological condition also provide useful data. For example, when we discuss amnesia (see Chapter 18), you'll see studies using chronic alcoholics who have acquired Korsakoff's syndrome. Also, there are systematic neurological changes that occur as a result of the natural aging process. Thus, age-related changes in memory can be viewed as neurological assessment of memory (see Chapter 17). Finally, some diseases, such as Alzheimer's, have systematic effects on the central nervous system. In these special populations, there is some regularity in the change that occurs, so we can observe a systematic change in neurological function that results in altered thoughts and behaviors. Of course, there may be some pre-existing conditions that can complicate an assessment—for example, epilepsy can alter the brain's organization and structure.

Special populations are advantageous sources of information because they provide a large number of people with a prespecified condition that has standard neurological changes associated with it. This allows for the removal of idiosyncratic changes that occur and present in case studies. Because these groups are large, it also allows for a better understanding of the condition and, hopefully, will lead to better treatments.

Stop and Review

A number of methods have been developed to assess brain structure and function. Some of these, such as CT and MRI scans, provide information about structural characteristics of a living human brain. Others allow researchers to look at brain function. Some of these are based on the electrical activity such as single-cell recordings, MEG scans, and EEG recordings, as well as measures that are derived from EEG recordings, such as ERP measures and assessments of event-related (de)synchronization. It is also possible to disrupt or modify electrical activity using TMS. In addition, changes in blood flow can be measure to assess neural activity, as with PET and fMRI scans. Finally, it is also possible to assess cases of brain damage, as well as groups of people who have well-known changes in brain function, such as the elderly.

THE PERMANENCE OF MEMORIES

When a person is thinking about something, different parts of the brain are active, depending on the particular contents of that thought. These reflect the active firing of the neural assemblies that correspond to the material at hand. The information that is currently being thought is short-term/working memory in the language of the modal model of memory. However, for information to be useful beyond the current moment it needs to be stored in a state that does not require active neural firing. The process of making memories stable beyond the current moment is called **consolidation**. So, new knowledge and experiences actually physically alters the structure of the brain over long periods of time. This is true, in some form, of every experience we have. Our brains, and our memories, are in a constant state of flux as we encounter new events, thoughts, and experiences.

A great deal of the evidence for consolidation comes from work on brain damaged individuals, particularly those with retrograde amnesia (see Chapter 18). Essentially, people are more likely to lose recent memories, while older memories remain intact (Nadel & Moscovitch, 1997). This is known as Ribot's gradient (Ribot, 1882). The idea is that newer memories have not yet been sufficiently consolidated, and so they are easier to disrupt in the face of head trauma. In comparison, older memories are more consolidated and so are harder to disrupt.

While memory consolidation is going on all of the time (Carr, Jadhav, & Frank, 2011), these processes become more intense when a person is sleeping (Rasch & Born, 2008; Stickgold, 2005). Even better, if you dream about what you learned prior to sleep you are more likely to remember it later (Wamsley, Tucker, Payne, Benavides, & Stickgold, 2010). Part of the reason we sleep is to provide our brain with an opportunity to engage in activities that are not possible or are less effective when we are awake. This improved memory with sleep is due to a decline in the loss or forgetting of memories rather than a boost of previously weaker memories (Fenn & Hambrick, 2013). These sleep benefits occur not only for nightly sleep, but any sleep that you get from taking a nap, although the benefit is greater for nocturnal sleep (Lo, Dijk & Groeger, 2014). Finally, in addition to sleep, some memory consolidation can also be boosted through physical exercise (McNerney & Radvansky, 2015; Voss, Vivar, Kramer,

& van Praag, 2013).

Improving Your Memory

This chapter covers issues about the underlying neuroscience of human memory. While it is easy to see how these issues are important for understanding how memory works, it may be harder to see how these topics can be used to improve your own memory. One issue covered here is the idea that memory consolidation is aided by sleep. This is a point that you can clearly apply to your own life. So, first off, you should try to get enough sleep each night. You will learn more quickly and hold on to information longer if you do. Additionally, information that is learned closer to when you fall asleep is more likely to benefit from the consolidation that occurs when you sleep. Thus, it is to your advantage to study material for your classes prior to going to sleep. Moreover, if you are fortunate enough to be able to nap during the day after your classes, you should do so.

The next section of the chapter discusses two kinds of consolidation, synaptic and systems consolidation (Alvarez & Squire, 1994; Dudai, 1996; Wixted & Cai, 2013), as well as the process of reconsolidation. It should be noted that our discussion is focused on declarative memory consolidation. There are consolidation processes for nondeclarative memories, but these involve different neural systems, such as the basal ganglia and cerebellum (e.g., Shadmehr & Holcomb, 1997).

Synaptic Consolidation

Synaptic consolidation is the creation of relatively enduring memories that have just been actively thought about. For declarative memories, synaptic consolidation occurs in the hippocampus through LTP. This is a relatively rapid process that involves information that is currently active in the firing neural assemblies of short-term/working memory. If people are given an opportunity to briefly rest (say 2.5 seconds) after viewing information, this gives synaptic consolidation an opportunity to occur without further incoming and interfering items (Bayliss, Bogdanovs, & Jarrold, 2015). Moreover, from what we know about LTP, we can estimate that synaptically consolidated memories may be retained for a few days or weeks. How ever, this type of consolidation is transient and is not the final permanent storage of memories. That is, while this is considered long-term memory for the modal model of memory, it is not permanent memory storage.

Systems Consolidation

After synaptic consolidation, there is a wider consolidation that occurs in larger brain systems (Abraham, 2006). Much less is known about **systems consolidation**, other than it involves long-term memories becoming more independent of the hippocampus. One study that did look at this was done by Takashima et al. (2009). They used fMRI recordings for remembering pictures of natural landscapes 1, 2, 30, and 90 days after learning. They found that neural activity in the hippocampus decreased over time. In contrast, activity in the cortex, particularly in areas of the frontal lobe, increased with greater retention intervals. Thus, as memories became consolidated in the cortex, the hippocampus became less involved and the cortex became more involved.

The Process of Consolidation

Memory consolidation is a multiple stage process (McGaugh, 2000; Meeter & Murre, 2004), as illustrated in the top of Figure 2.11. After information has been perceptually encoded, it is held in an active state where it can be manipulated. However, when new information is processed, this information quickly becomes lost. This is illustrated by the blue curve in the graph at the bottom of Figure 2.11. This corres ponds to short-term/working memory in the modal model.

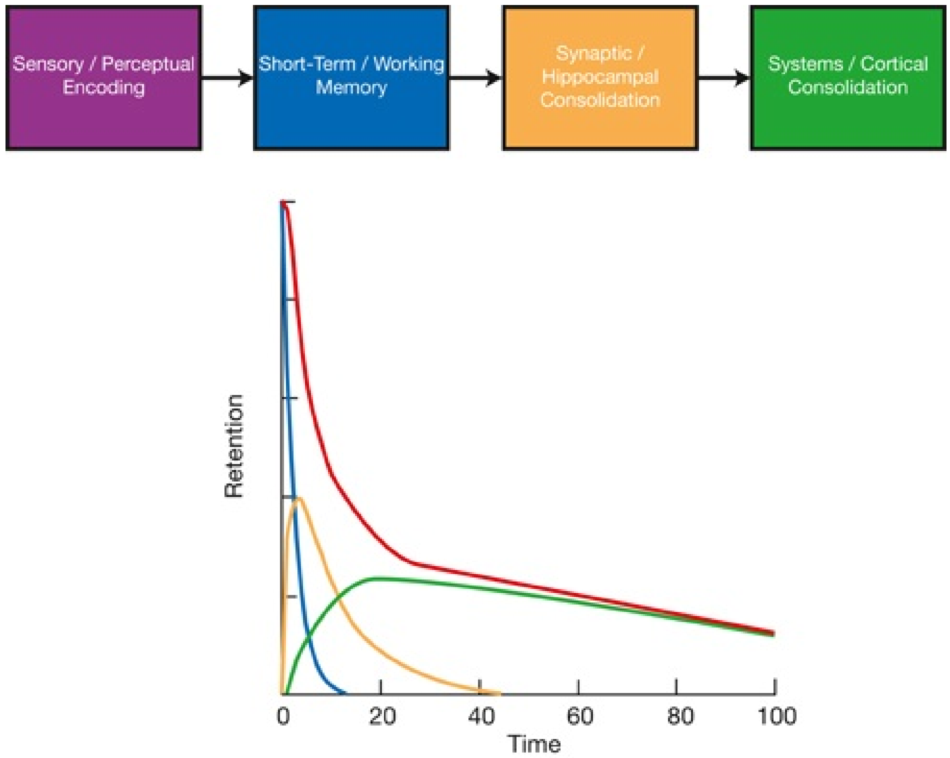

FIGURE 2.11 *Trajectory of Availability as a Result of Various Consolidation Processes*

Information that is active in short-term/working memory can undergo the process of synaptic consolidation associated with the hippocampus. Information is initially consolidated relatively rapidly, within a few seconds or minutes. It then remains available in this system for several days or weeks. This is illustrated by the gold curve in Figure 2.11. This stage corresponds to long-term memory in the modal model.

The final stage is systems consolidation, which occurs in the cortex for information held in the hippocampus. Information takes much longer to be consolidated in this system, anywhere from several minutes, day, weeks, months, or years. No one really knows at this point. These memories are retained for long periods of time, up to a lifetime, although there is likely to be some loss over time. This is illustrated by the green curve in Figure 2.11. This stage also corresponds to long-term memory in the modal model.

What should be noted further about Figure 2.11 is the line in red. This is the availability of a given memory trace. It is the sum of the three other com ponents. This is a negatively accelerating function, as is observed with Ebbinghaus's for getting/retention curve. This is the case despite the fact that the three functions that give rise to it each have different shapes. Thus, the forgetting curve that is derived from memory data may reflect the operation of multiple, different underlying processes that each have their own characteristics.

Reconsolidation

As memories become more consolidated, they become less prone to forgetting. And, for the most part, this is what seems to happen. However, this does not mean that consolidated memories cannot be changed. A process of **reconsolidation** can occur when a memory that has been consolidated is later remembered. This causes it to be reactivated and this reactivated memory is then reconsolidated. What is interesting is that during reactivation a memory enters a fluid, malleable state where it can be changed! This is another example of the principle that remembering can cause forgetting. That said, the older and more strongly consolidated a memory is, the less malleable it is following retrieval and the harder it is to change. While consolidation and reconsolidation use similar neurological processes, there are some ways that they differ. That said, there is also some suggestion that reconsolidation is just a portion of the entire process of consolidation (Alberini, 2005).

There are two ways for memories to be altered during the reconsolidation. The first is for information to be lost from the original memory. If a consolidated memory is retrieved and then disrupted, the consolidated memory is lost. For example, in a study by Nader, Shafe, and LeDoux (2000), rats were trained to fear an aversive stimulus (a tone paired with a foot shock). After their fear memories had con solidated, the rats were reminded of the original fear-inducing events. During this time, the rats were given an infusion of a protein synthesis inhibitor, causing the consolidated memories to be disrupted. This disruption did not occur if the inhibitor was given when the rats had not been reminded of the unpleasant events.

Similarly, in a study with humans, Schwabe and Wolf (2009) had people recall autobiographical events from their lives. Then, immediately after, they had people memorize a story or not. This immediate memorization disrupted people’s memories for events from their own lives. People who memorized the story later remembered fewer autobiographical events, although this was limited to neutral events, not emotionally positive or negative events.

The other way for reconsolidation to have an influence is for new information to be added to a memory trace. Here, a previously consolidated memory is retrieved and then new information is presented at the same time. This new material is then incorporated into the memory. For example, in a study by Forcato et al. (2007), people were given lists of words to remember. Then, after that memory had consolidated over 24 hours, people were reminded of the first list and were also given a second list. They found that the new list words were incorporated and reconsolidated with the original list. In other words, when people remember an event from their past and also encounter new information at that time, this new information may be reconsolidated with the original memory, changing it.

A potential practical use of reconsolidation may be to help people who have troubling memories from their past, as with post-traumatic stress disorder (PTSD). By altering or removing them, these people would be less tortured by these memories. This idea is still in its infancy and its effectiveness is uncertain. There is some evidence that it may be possible to some degree (Kroes et al., 2014; Weems et al., 2014). However, there have also been failures to find any effect (Wood et al., 2015).

Neurogenesis

Another process that may aid in the formation of permanent memories is **neurogenesis**. While you already have most of the neurons you'll have to work with, you brain is still creating new ones all the time (Gage, 2002). Thousands of new neurons are created in the hippocampus each day (Shors, 2014). However, the fate of many of these new neurons is to die off. That said, there is some evidence that, if an organism engages in new learning during the day, more of these newly created neurons will stick around, perhaps because they become part of networks of knowledge created during learning. This can be seen in Figure 2.12. Thus, it seems likely that the more you learn during the day, the more of these new neurons you will retain. This gain in neural mass can then aid your ability to learn even more information later. So, study hard.

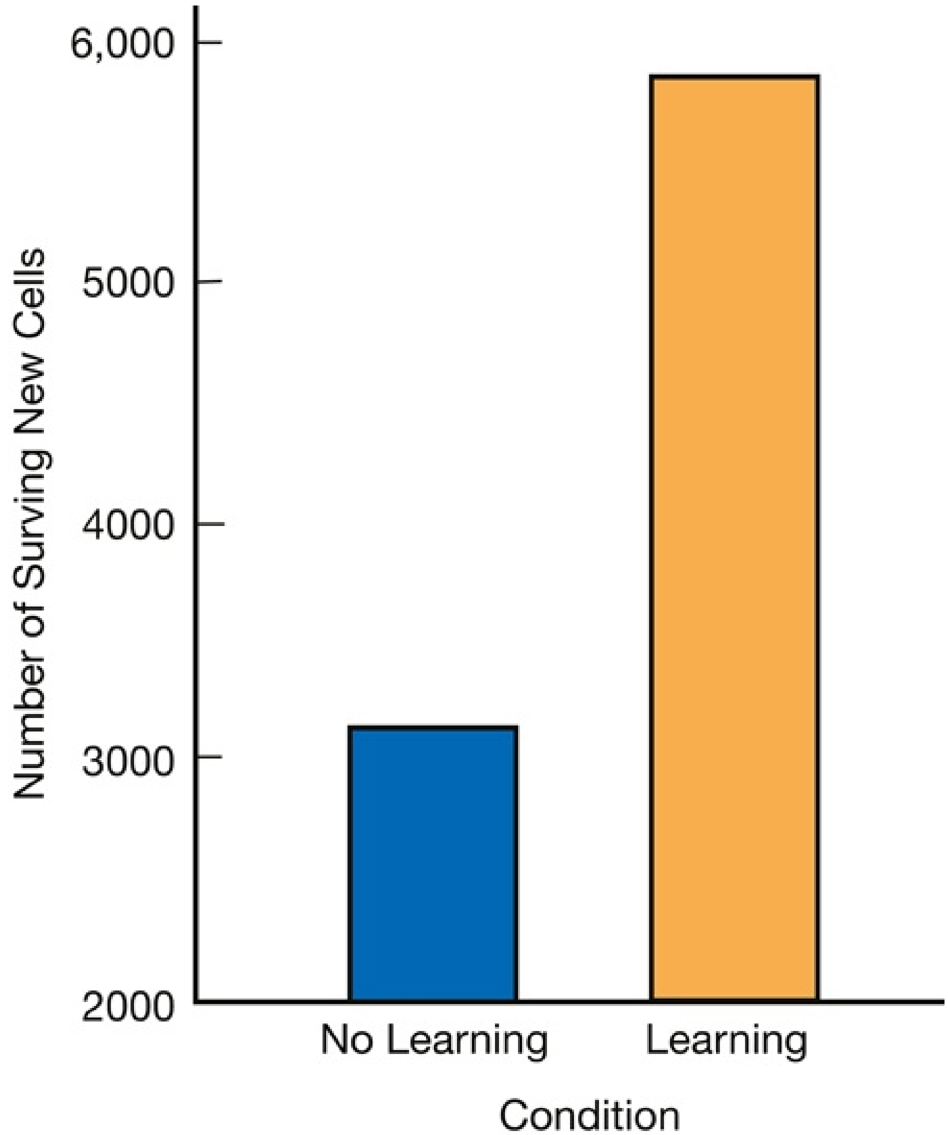

FIGURE 2.12 *Number of Surviving New Cells from Neurogenesis After Either a Period of No Learning or the Learning of New Information*

Adapted from: Shors, T. J. (2014). The adult brain makes new neurons, and effortful learning keeps them alive. *Current Directions in Psychological Science*, *23*, 311–318

Stop and Review

Memories become permanent over time through the process of consolidation. Early on, there is a phase of synaptic consolidation in the hippocampus. Then, there is a slower phase of systems consolidation involving more broad-based cortical processes. Consolidated memories can be changed by reactivating and reconsolidating them. This involves either removing information from a memory or adding new information. Finally, memory permanence can be aided through neurogenesis.

PUTTING IT ALL TOGETHER

Memory depends on the operation of the nervous system, and its structure can be assessed using CT and MRI scans. The acts of remembering and forgetting involve multiple sites and different changes in the nervous system during the processes of encoding, storage, and retrieval. The encoding of new memories involves a change in the dendrites of your neurons. This can be seen changes in the firing rate of individual neurons using single-cell recordings. Of course, neurons are working together as part of cell assemblies, cortical nuclei, substructures, and complexes of networks working together, as with the default mode network.

The storage of new memories through changes in neural connections is part of the process of consolidation. This first involves synaptic consolidation in the hippocampus, followed by systems consolidation across your cortex. While consolidated memories can be stored for long periods of time, it is also important to keep in mind that your memories can change either through disruptions, such as external electrical activity such as ECT, or, less dramatically, through a process of reconsolidation. Finally, the process of neurogenesis can also influence the long-term storage of new information.

Retrieval is observed by looking at changes in electrical activity in the brain from the sum of action potentials, and from changes in blood flow as neurons work harder. Your brain's electrical activity can be assessed using EEG and MEG scans. EEG recordings can be exploited to assess ERP waves and changes in the neural (de)synchronization. We can use changes in blood flow using PET and fMRI scans. These sorts of measures reveal the use brain areas that are centrally important for memory processing, such as the temporal lobe, the hippocampus, the amygdala, the basal ganglia, and the diencephalon.

STUDY QUESTIONS

1. What are the basic components of a neuron?
2. How does the nervous system communicate information? What is the electrical component? What is the chemical component?
3. How do neurons change in order to encode information into memory?
4. What are the lobes of the cortex and how are they involved in memory?

What do characteristics such as the default mode network mean for how the cortical lobes work?

5. What is the hippocampus, and how is it critically involved in memory? What are other subcortical structures that have an influence on memory?
6. What are some of the various neuroimaging methods available? Which are good for assessing structure? Which are good for recording electrical activity? Which are good for recording blood flow?
7. In what ways can changes in brain structure be used to assess memory?
8. How do memories become more permanently stored in the brain?
9. What is the difference between the various types of consolidation and what is the difference between consolidation and reconsolidation?
10. How does neurogenesis contribute to the formation of memories over long periods of time?

KEY TERMS

- Acetylcholine (Ach)
- action potential
- amygdala
- axons
- basal ganglia
- Brodmann areas (BA)
- case studies
- cerebellum
- computer-assisted tomography (CT)
- consolidation
- default mode network (DMN)
- dendrites
- diencephalon
- dopamine
- electroencephalography (EEG)
- emergent property
- event-related desynchronization (ERD)
- event-related potential (ERP)
- event-related synchronization (ERS)
- frontal lobes

- functional magnetic resonance imaging (fMRI)
- GABA
- glutamate (Glu)
- hippocampus
- hypothalamus
- laterality
- long-term depression (LTD)
- long-term potentiation (LTP)
- magnetic resonance imaging (MRI)
- magnetoencephalography (MEG)
- myelin sheath neurogenesis
- neuron
- neurotransmitters
- nodes of Ranvier
- norepinephrine
- occipital lobes
- parietal lobes
- positron emission tomography (PET)
- reconsolidation
- single-cell recording
- soma
- special populations
- subtractive method
- synapse
- synaptic consolidation
- systems consolidation
- temporal lobes
- terminal buttons
- thalamus
- transcranial magnetic stimulation (TMS)

EXPLORE MORE

Here are some additional readings that you can explore to provide you with better insight into the neuroscience of memory.

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NOTE

1 Oligodendrocytes in the central nervous system and Schwann cells in the peripheral nervous system.

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CHAPTER 3

Methods and Principles

Memory is an intimate part of who we are. However, despite the fact that it permeates all mental processes (or perhaps because of this) we have little conscious awareness of it. Intuitively, memory seems very ethereal. As described in Chapter 1, for most of history memory was thought to be beyond objective study. It wasn't until the late nineteenth century that it became sensible to think about systematically studying memory. Because it is so difficult, if not impossible, to get a direct look at memory, we need reliable indirect methods to measure and assess it. For scientific study, we need *empirical evidence* of memory representations and processes. These methods often involve an experimenter manipulating what is to be remembered, recording an act of remembering, and then making inferences about memory based on what is observed. This may sound like an artificial process, but it's not unlike how other sciences proceed or how we conduct our day-to-day lives. For example, astronomers looking at computer readings can draw conclusions about planets circling distant stars without ever laying eyes on them.

In this chapter we first address what an experiment is and how it compares with other types of data collection. Then we examine various methods of memory research. We first look at the learning situation, followed by tasks that can be used to test memory contents and structure. Finally, we consider issues of conscious introspections. Along with each of these methods we look at some basic, well-established principles of memory whose discovery can be attributed, at least in part, to these methods. For those interested students, ways of calculating some memory measures, perhaps for a laboratory section or a research project, are provided in the appendix.

COMPONENTS OF MEMORY RESEARCH

We approach memory from a scientific perspective to gain an objective understanding and minimize personal biases. As such, the ideas about memory covered here reflect the work of scientists. To help you better understand how these people do their job, we first discuss what an experiment is and the different types of variables a researcher measures and controls.

What Is an Experiment?

Most of our knowledge of memory comes from experiments. So, just what *is* an experiment? An **experiment** is a controlled situation in which a researcher manipulates variables of interest, measuring the effect of this manipulation, while keeping the irrelevant variables as consistent as possible. Furthermore, participants are randomly assigned to different conditions to reduce any unwanted systematicity. Let's unpack what the components of an experiment are and what they mean.

In an experiment, there are two variables that are of primary interest: the independent variable and the dependent variable. The **independent variable** is the variable that is being manipulated by the researcher. Independent variables in a memory experiment might be how much information people have to remember, how long they have to remember it, and so on. For example, suppose you are doing an experiment in which you want to know whether students learn better by studying consistently throughout a week or by cramming right before their memory is tested. You could test this by making the type of studying your independent variable. You would randomly assign people to two conditions. Condition A would be studying consistently and condition B would be cramming. The fact that these variables are being manipulated gives the researcher a great deal of control. In our example, you would be fairly confident that any memory differences you observed would be due to how people studied because you manipulated this independent variable.

PHOTO 3.1 *Performing experiments is critical to an objective and accurate understanding of human memory*

Source: Wavebreakmedia Ltd/Wavebreak Media/Thinkstock

The other variable of primary interest is the **dependent variable**, the one being measured. Dependent variables in a memory experiment might be how much is remembered, how accurate the memories are, how fast they remember, and so on. Continuing our example, in assessing whether studying consistently or cramming resulted in better memory, you might decide to use the number of correct answers on a multiple-choice test as your dependent variable. You could then assess whether people score higher in condition A or condition B.[1] Different dependent variables have different advantages and disadvantages, and these are explored when we discuss different measures throughout this chapter. Which dependent variable is selected in an experiment is a function of what theory or ideas about memory are being tested.

Irrelevant aspects of the situation are known as **control variables**. A control variable is any aspect of the experiment that could potentially have an impact on the observed results but is not a factor of interest. Control variables can include things such as the room lighting, the instructions, the apparatus used, and so on. For example, suppose for a learning study if people in condition A are always tested in room 261, people in condition B are always tested in room 265, and room is not a variable of interest in the study (and it is not clear why it would be), then there is an unwanted systematicity and the results would be problematic because conditions are confounded with testing room. That is, you did not adequately account for a control variable that should have been held constant. This could have been done by having half of the people in each group be tested in each of the two rooms. A good experimenter works to make sure that control variables are not confounded with the independent variables to ensure that the results are interpretable.

Other Types of Studies

An experiment is not the only way to gather information about memory. Other methods are suitable when experimental control is difficult or impossible. One alternative is a **correlation** study , where the performance of a dependent measure is assessed as a function of some pre-existing circumstances. For example, one can look at memory as a function of age. Age cannot be experimentally controlled but it is information that can be used to make inferences about memory.

Alternatively, a researcher may do a **quasi-experiment** in which pre-existing conditions are combined with some controlled assignment of the independent variables—for example, suppose there are two classes. In each class students memorized a set of 100 words and a set of 100 pictures. Here, the assignment of people to conditions is not random but based on the classes they are already in. However, the type of materials learned is manipulated as it would be in an experiment.

Finally, in some situations, it is not possible to assess memory in large numbers of people. Instead, the researcher can do a **case study**. When we look at the effects of brain damage, we can assess memory in specific individuals because they are the only ones with a specific type of deficit.

Theories and Hypotheses

For each study of memory, a researcher should have a theory of how memory works, or at least some part of it. A **theory** is a principled explanation for how some process in the world is structured or operates. For example, a theory of gravity is an explanation for how gravity works. A theory of evolution is an explanation of how evolution unfolds. A theory of memory is an explanation of how memory works. Scientifically, saying that something is theoretical does not necessarily mean that the phenomenon is hypothetical. No rational person would question the existence of human memory. Instead, saying that something is a theory of a phenomenon means that it is an explanation or account of it. Of course, a theory can be wrong or have elements that are incorrect, but this does not deny that there is a phenomenon in the world to be explained.

In memory research, theories can be broad and encompassing explanations of large aspects of memory or they can be narrow and focused explanations of a specific phenomenon or finding. What kind of theory researchers are working with is a function of their goals and the need to keep things tractable. Memory and cognition are incredibly complex. It is nearly impossible for a researcher to track each and every aspect of memory when conducting any given experiment. Part of this comes from the fact that, for a given task, not every memory representation and process that a person possesses is going to come into play. For example, if you are trying to remember if a word was on a list that you just studied, your memory for how to play the piano is unlikely to be of much importance. Thus, memory researchers are better off using mini-theories that focus on the more important and relevant memory representations and process that are of interest.

Using a theory, one can derive a hypothesis about the outcome of a study. A **hypothesis** is an educated guess or prediction about how the variation of the independent variables is related to the outcome of the dependent variables. Typically, this is cast in some theoretical language about how memory is operating in the context of the experiment. To better advance our understanding of memory, it is often advantageous not to test a single hypothesis but to test two or more hypotheses, each derived from different theories. In doing so, we can distinguish between different explanations of how memory works to decide which account is closer to the truth of the situation. In this way, we can accept some theories, reject others, or, in some cases, modify existing theories to better capture the patterns observed in the data to allow us to gain more accurate understandings.

Stop and Review

There are a variety of ways to study memory. The most common way is to do an experiment in which you have control over the variables of interest and can better assess what is affecting the outcome. The independent variables are what is manipulated, the dependent variables are what is measured, and control variables are factors that could affect the outcome and so are either held constant or randomly varied. In addition to experiments, you can do correlational, quasi-experimental, and case studies. These allow for tests of memory in circumstances where some factors cannot be explicitly manipulated. Finally, scientific studies of memory require theories to provide explanations for how information is represented and processed. From these theories you can derive hypotheses. Studies provide the data to support or refute theories or encourage theory modification.

ASPECTS OF LEARNING

To properly assess memory, some information must first be learned. How this happens is important. Was the material something that was consciously learned or was it something that was just picked up along the way? What kind of information was it, pictures or words?

Intentional Versus Incidental Learning

Methods. An important factor in memory research is whether people explicitly try to learn. Explicit memorization is called intentional learning. The alternative is that a person just happens to learn something during the course of other activities. This is called incidental learning. Intentional learning is when you study for this or any other class. Incidental learning is knowledge that you've picked up without having to try, such as knowing how many movies you've seen in the past month.

An experimenter can explicitly alert people that the material they are given is going to be tested for later. These intentional learning instructions are direct and they lead people to treat information more elaboratively. This can involve building upon the information in some way, such as making inferences or creating mental images. This elaborative processing profoundly affects memory. Alternatively, if an experimenter gives incidental memory instructions, they are having the person attend to and think about the information, but not expend any extra effort memorizing it. In such cases, a cover task is given to orient people to the material. These cover tasks vary and they can include things such as pleasantness ratings, sensibility ratings, or sorting items into categories. So, these cover tasks direct people's attention to the material, allowing for the possibility for it to be stored in memory even though people are unlikely to be actively memorizing it.

Principles. In general, memory is better with intentional than incidental learning (see Block, 2009, for a review). This section outlines principles of memory that demonstrate the importance of the type of learning: levels of processing, mental imagery, the generation effect, and the automaticity of encoding.

An example of the influence of effort exerted during memorization is the **levels of processing** framework (Craik & Lockhart, 1972). This refers to the degree to which people elaborate on information during study. When people try to learn, they may simply repeat the information over and over. This is called **rote rehearsal**. In general, recall memory does not improve much with rote rehearsal, and recognition is only slightly improved (Glenberg, Smith, & Green, 1977). An example of the poor effectiveness of rote rehearsal is the results of a study by Nickerson and Adams (1979). In this study, students at Brown University were shown individual drawings of pennies like those in Figure 3.1. They were asked to indicate whether each was correct. See if you can remember which penny is the correct one. Students in this study were able to identify the correct drawing only 50% of the time. The penny that had the highest rate of acceptance was an incorrect version (with 67% of the students saying it was correct).[2] Thus, repeated exposure to something does not improve memory.

In contrast, the more people think about the meaning of information, the more likely they are to use knowledge that they already have, making inferences and elaborating on the to-be-learned information. This connecting and generation of knowledge to build on the information that is given is called **elaborative rehearsal**.

Information that receives little elaboration is processed less. For example, suppose a task is to think about a set of words and only say whether each is printed in upper- or lowercase letters. This is a shallow level of processing because it requires little attention to meaning and prior knowledge. However, if the task is to determine whether the word makes sense in a sentence this is a deeper level of processing. In some sense, shallow processing evokes more incidental learning, whereas elaborative processing is more like intentional learning, although there may not be an overt effort to memorize. The levels of processing effect occur for both incidental and intentional encoding (Hyde & Jenkins, 1973), although it is more likely to be observed with intentional learning.

FIGURE 3.1 *Which Penny Is the Correct One?*

Adapted from: Nickerson, R. S., & Adams, M. J. (1979). Long-term memory for a common object. *Cognitive Psychology*, *11*, 287–307

One way to elaborate on information, and engage in deeper processing, is to use **mental imagery** to create a mental picture of what is being learned. As an example, to remember that you need to get some green peppers and a loaf of bread at the grocery store, you might form a mental image of a green pepper sandwich. The use of mental images improves memory (Schnorr & Atkinson, 1969), as shown in Figure 3.2, in this case for students at Stanford University. Memories are better when you form mental images than when you simply rehearse the information. You need to make a concerted effort to form mental images. They do not appear spontaneously.

The benefit to memory of mental images led to the development of **dual code theory** (Paivio, 1969). According to this view, people store information in memory in at least two forms: a verbal/linguistic code of what they are reading or hearing and a mental image code that they create from their imaginations. These two codes can be associated to each other if they refer to the same thing. One code is a verbal code for the words that were read and the other is an image code of the mental picture that was created. Memory improves because, with mental imagery, there are multiple memory retrieval pathways to the same information and more memory traces containing the desired information. This makes successful remembering more likely.

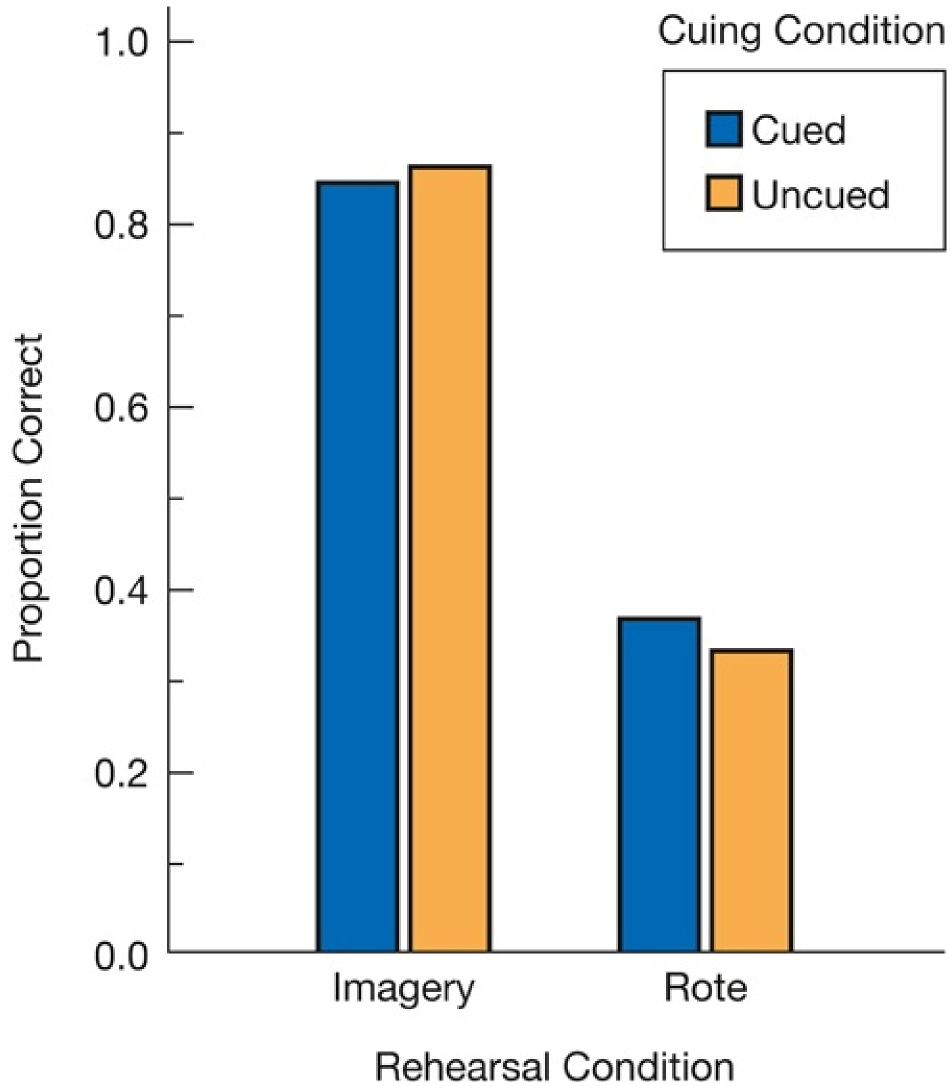

FIGURE 3.2 *Impact of Mental Imagery on Later Memory*

Adapted from data reported in: Schnorr, J. A., & Atkinson, R. C. (1969). Repetition versus imagery instructions in the short- and long-term retention of paired-associates. *Psychonomic Science, 15*, 183–184

For the levels of processing framework, the more information is elaborated, the better it is remembered. This is shown by the **generation effect**: Information that a person generates is remembered better than material that is simply read or heard (Slamecka & Graf, 1978; for a meta-analysis, see Bertsch, Pesta, Wiscott & McDaniel, 2007). For example, suppose people are presented with a series of word stems, such as TAB_____, with the task of completing the word. This is a generation task because the person is generating the rest of the information. Alternatively, if people simply read a series of complete words, this is not a generation task because nothing is being created. As a more everyday example of the generation effect, think of your conversations from the past week. What do you remember best from them? Typic ally, it will be the things that you said. This is because you generated those statements. The generation effect extends to a wide variety of information, including memory for the context in which something was learned (Marsh, Edelman, & Bower, 2001).

A generation effect is also observed when people solve a puzzle or a problem. This is called the **“aha” effect** (Auble, Franks, & Soraci, 1979). For example, a person may have trouble initially understanding a sentence such as “The man’s back ached because the ends were too large.” At some point, there is an awareness that this sentence is about using barbells and people have an “aha” experience. Because people generated their own solutions, memory is better. Similarly, if people complete a connect-the-dots puzzle, the picture is remembered better than if it was seen already assembled (Wills, Soraci, Chechile, & Taylor, 2000).

In addition to generating words and ideas, memory is better when people actually perform a task rather than watch someone else do it or read about it. This is the **enactment effect** (Engelkamp & Zimmer, 1989). Like the generation and “aha” effects, this involves elaborative rehearsal (Senkfor, Van Petten, & Kutas, 2008). Any type of performed action seems to produce this benefit and seems to take advantage of embodied aspects of cognition. However, note that this memory benefit only occurs when a person enacts only some of the items, not all of them (Dodd & Shumborski, 2009). People are mentally organizing and structuring information differently when they perform the action (Koriat & Pearlman-Avnion, 2003).

A cousin of the enactment effect is the **production effect** (MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010; see Fawcett, 2013, for a meta-analysis), in which people are asked to either say aloud what they are trying learn, or read it silently. The finding is that people remember more if they read things aloud (they “produce” them) than if they do not. The production effect is not limited to saying things aloud. It can also occur if people mouth the material, whisper it, write it, or even type it (Forrin, MacLeod, & Ozubko, 2012). The production effect has been found when words are signed (as with American Sign Language) (Zimmer & Engelkamp, 2003).

PHOTO 3.2 *The production effect, the finding that saying things aloud, or even writing them down, can improve memory, shows the importance of going beyond simple reading*

Improving Your Memory

This chapter provides a wealth of information about how to improve your memory using basic principles that we covered here. For example, using the depth of processing framework as a guide, you've learned that the more you exert some effort to deeply process information, the more you will remember later. This can be done by elaborating on the material that you are trying to learn, forming mental images of items covered, acting things out if you can, or at least saying things aloud or writing them down, and so on. A good step that you can take to achieve this is to write a summary of the class material after you have completed your readings or listened to a lecture. This provides more organization of the information, causing you to mentally elaborate on it, leading to better memory, and reducing the amount of study time you will need later. The more often you do this with the material, the more overlearning there will be, the stronger your memories will be, and the better you will do in your courses. This sounds like a lot of extra work. However, most of the extra work is done up front. By taking these steps, you may exert less work on the whole, possibly leading you to spend less time studying overall because you are being more efficient and effective with the time that you do have.

Finally, it should be noted that, under some conditions, the type of learning does not matter much. Memory can be similar with incidental and intentional encoding, depending on how people think about the information at the time (Postman & Adams, 1956) and intentional/incidental effects may not be present on certain memory tests, such as recognition (Eagle & Leiter, 1964). In some cases, there is an **automaticity of encoding** (Hasher & Zacks, 1979, 1984) in which information is stored in memory with little effort. Because the information is automatically encoded, further efforts at learning do not provide additional benefit. Some types of information that are more automatically encoded are knowledge of event frequency, time, and location. For example, think of how many times in the past month you've eaten out. The answer comes to mind relatively easily, and it is unlikely that you deliberately learned this as it was occurring. If you think about the knowledge that you have, some of it was very easy to learn, whereas some of it was learned only with a great deal of effort.

Stop and Review

When exploring memory, one of the things that you need to take into account is whether the material was learned intentionally or incidentally. The levels of processing framework is a central principle of memory that is oriented around the idea that how much attention and processing a set of information receives during learning affects later memory. The more deeply that information is processed, the better it will be remembered later. Various ways to deeply process materials include forming mental images as well as generating and producing information. Finally, some types of information are more automatically encoded into memory. In these cases, intentional encoding does not improve memory much beyond what is learned more spontaneously and incidentally.

Stimulus Characteristics

During learning, it is possible to manipulate not only what a person is doing but also the nature of the information itself. As has already been mentioned, some types of knowledge are easy to learn and remember. In contrast, others require more effort and are more likely to be forgotten.

Methods. When studying memory, it is important to take into consideration what research participants think about the experiment. An adequate task analysis must be done. If not, it is possible that the researcher and the participant may interpret the task in different ways. What an experimenter thinks the participant is memorizing is the nominal stimulus. The stimulus the participant identifies and thinks about is the functional stimulus. Usually these are the same thing, but in some cases they are very different. For example, a researcher might give people a list of nonsense syllables, one of them "DAX." In the experimenter's mind, this is just a meaningless series of letters. However, if the participant is an avid Star Trek fan, he or she would recognize this as the name of a character in the series.

Principles. Memory can vary depending on the nature of the materials being memorized. This section outlines principles of memory that have been derived from explorations with different stimuli, including the principles of savings, the influence of using pictures and concrete materials as compared to verbal and abstract materials, and the roles of emotion and frequency on memory.

Stimuli affect memory in a number of ways. One of these, discovered by Ebbinghaus (1885/1964), is the principle of **savings**. After information has been learned and forgotten, a person requires less effort to learn it a second time. For example, if it took you 10 repetitions to learn something the first time through and only three repetitions the second time, this would be a savings of seven. The principle of savings is important for two reasons. First, this nicely illustrates the fact that although we may not be consciously aware of knowledge from our past it may still affect our ability to learn and remember. Second, it shows that information we already know something about, even if we're not conscious of it, is easier to remember than something we encounter for the first time. In general, the more information taps into our prior knowledge, the easier it is to remember. Thus, the meaning of a stimulus varies from person to person depending on the individual's experiences with and knowledge of it.

In general, humans are visual animals. As such, it is not surprising that pictures are remembered better than words (Shepard, 1967; Standing, 1973). This is the **picture superiority effect**. It occurs because we are better attuned to processing perceptual than linguistic information. Also, a picture is more likely to be unique and contain a higher degree of detail. However, even pictures can vary in how easily they are remembered depending on how meaningful they are. For example, people find it easier to remember pictures of faces than pictures of snowflakes or inkblots (Goldstein & Chance, 1970). Moreover, the picture superiority effect can be magnified with dynamic images (e.g., video) over static images (Matthews, Benjamin, & Osborne, 2007).[3]

Pictures and words are treated differently by memory, even at a neurological level. The right part of the hippocampus is more active for processing pictures, whereas the left is more active for processing words (Papanicolaou et al., 2002). Furthermore, using fMRI scans, Vaidya, Zhao, Desmond, and Gabrieli (2002) found that during the encoding of pictures there is bilateral activation of the fusiform area (BA 37), the lingual-medial occipital lobe (BA 18, 19), and the inferior temporal gyrus (BA 20). Moreover, a subset of these areas, namely the fusiform area and the inferior temporal gyrus, is also activated during retrieval for items studied as pictures, even if the memory probes are words. So, the picture superiority effect reflects the use of a broader range of brain regions.

It has also been found that concrete information—words like “car,” “house,” or “book”—are remembered better than abstract information—words like “truth,” “betrayal,” or “redemption.” This is the **concreteness effect**. Concreteness may aid memory because it involves more perceptual qualities: Concrete information is more likely to be supported by an additional image code. This distinction between concrete and abstract information is supported neurologically. Concrete words are associated with greater basal extrastriate cortex activation (BA 19), suggesting more perceptual processing (although there is some involvement for abstract information as well: Martin-Loeches, Hinojosa, Fernandez-Frias, & Rubia, 2001). Finally, there is greater activation of the right hemisphere for concrete words, whereas abstract words tend to involve more left hemisphere processing (Kounios & Holcombe, 1994).

Memory can also be influenced by **emotions**. Emotional memories are often better remembered than neutral memories (Kensinger, 2009; Kleinsmith & Kaplan, 1963; Phelps, 2006). Moreover, emotional memories are more vivid and contain more detail (Kensinger & Corkin, 2003). Emotional information seems, over the long term, to be preferred for consolidation during sleep (Payne & Kensinger, 2010). Less emotionally intense emotions tend to involve an influence of the frontal lobes (LaBar & Cabeza, 2006), whereas more intense emotions involve an influence of the amyg dala. This then carries over and affects memory functioning in the hippocampus and medial temporal lobes, perhaps because the amygdala helps direct attention to more emotionally relevant aspects of the world, although this may come at a cost to less emotional details (see Mather, 2007 for a review). More emotionally intense events may affect memory because of their more primitive, visceral, and survival-based qualities. In contrast, emotional, but less intense, events may influence memory based on their seeming importance.

In addition to emotional intensity, memory may be affected by emotional valence, that is, whether an event is emotionally positive (e.g., “courage”) or negative (e.g., “ordeal”). According to the **Pollyanna principle**, there is a tendency to remember positive information better than negative information. For example, positive words are learned more quickly than negative words (Anisfeld & Lambert, 1966; Stagner, 1933). However, there are circumstances where negative information is remembered better than positive information (Ortony, Turner, & Antos, 1983), such as with flashbulb memories for surprising, and often negative, events (see Chapter 12). Negative words are learned faster than emotionally neutral words (like "wood") (Carter, 1936; Carter, Jones, & Shock, 1934). Finally, relative to neutral information, negative memories are more likely to benefit from the consolidating effects of sleep (Payne, Stickgold, Swanberg, & Kensinger, 2008).

Another stimulus quality that can affect memory is **frequency**, that is, how often a given item is encountered. Typically, word frequency is operationalized in terms of how often a word occurs in the language. Frequency is a bit odd in some respects. Memory is better for frequent information for recall tests (Taft, 1979) but it is better for rare information for recognition tests. Common things are easier to recall because there are more ways to get at them, which makes them more likely to be recalled. However, with recognition, less frequent items have fewer competitor memory traces, so they are recognized more easily (see the following sections on recall and recognition).

Stop and Review

Learning is also influenced by the nature of the materials that are memorized. When evaluating memory, it is best to first do a task analysis of how a participant will view what is being done to make sure that there is an appropriate understanding of what the nominal and functional stimuli are. The principle of savings illustrates that even material that was previously learned, but which people claim has been forgotten, may still have representations in memory. Also, some types of material, such as pictures and concrete concepts, are easier to learn than others. This may reflect embodied aspects of memory. Moreover, information that is emotionally charged is easier to remember than neutral content. Over time there is a bias to remember positive memories more than negative memories, following the Pollyanna principle. Finally, how frequent or commonly materials are encountered can influence memory, with more frequent things being easier to recall but less frequent things being easier to recognize.

ASSESSING THE CONTENTS OF MEMORY

Questions about memory often center on issues of what knowledge is in memory, what can be remembered later, and how easily it is remembered. There are a number of ways of getting at the contents of memory, and each has its advantages and disadvantages.

Recall

Methods. A straightforward way to test memory is a recall test. For recall, people need to generate and report whatever they can retrieve from memory. There are many types of recall tests and several of them are considered here, namely free recall, forced recall, and cued recall.

The most basic type of recall test is **free recall**, in which people report as much information as they can. This is similar to answering an essay question on an exam. Because there is very little additional information provided, free recall is a good way to find out what a person knows well. Presumably, what is known well is what is reported. Information that is known, but not very well, is less likely to be reported because people are less likely to successfully retrieve it, or they may not have confidence in the memory and so hold back their responses.

Free recall data is not only appropriate for knowing what people accurately remember but it can also be used to study errors of omission (what people don't remember) and errors of commission (information that is reported, but was not, in fact, part of the event). Errors of commission are called **intrusions** and they can be important when studying false memories (see Chapter 13). Moreover, studying **recall order**, that is, the order in which people report things on a free recall test, can give some insight into how memories are structured. For example, when recalling sports teams, people may recall teams in the same division or conference together, suggesting that this this knowledge is stored together in memory. Also, stronger, better stored memories are more likely to be reported early in free recall, whereas weaker, less well known memories are likely to be reported later.

One problem with free recall is that there might be information that people remember, perhaps faintly, but that they are unwilling to report because they lack confidence in those memories and do not report them in case they might be wrong. Also, sometimes people report memories more generally when they have more precise knowledge that they may be withholding (Goldsmith, Koriat, & Weinberg-Eliezer, 2002). One way to encourage people to report weaker memories is to give a **forced recall** test. Unlike free recall, where people can report as much or as little as desired, in a forced recall test people are forced to report a certain amount of information. For example, if people were presented with a list of 20 words to learn, they could be asked to report 20 items on a forced recall test. Typically, the amount of information reported on a forced recall test is more than what would have been reported under free recall.

Using this approach, weaker knowledge in memory can be assessed as being present in some way. Typically, weaker knowledge is provided toward the end of forced recall. Forced recall can also be used to elicit intrusions that might otherwise be withheld. These errors can be informative about the processes people use to recover memories by illustrating how those processes can break down. In other words, the mistakes that people make are not random but follow certain principles. Studying these errors can provide insight into how memory works.

Memories are often associated with a context or setting. There are many things in the environment that can serve as context. To study how context influences memory retrieval, a **cued recall** test can be used. During memorization, people learn a set of information. The experimenter designates some of this information as target information to be recalled. Associated with this are other sets of information that serve as retrieval cues. Thus, the experimenter is controlling the context that will be relevant later. The paired associate learning tasks discussed in Chapter 1 are a good example of this sort of cue and target knowledge learning.

During retrieval, the experimenter provides a set of cues and the task is to report the information that goes with those cues. For example, if a person learned the word pair "goose–marble," the experimenter would give the word "goose" and the participant would need to recall the word "marble." Thus, the experimenter controls the context and can observe how it influences memory. Retrieval in cued recall tests is more constrained than under free recall conditions. During cued recall, people respond to either as many cues as they can or to all of the cues, much like a forced recall test. Again, both accuracy and errors can be used to help understand the contents of memory.

During recall, people need to mentally organize the information to be able to retrieve it later. This includes both recalling information that has not yet been reported as well as avoiding reporting something that has already been recalled. To monitor memory retrieval, people often develop a strategy known as a **retrieval plan**. This is a set of self-generated retrieval cues used to guide a person through the material. If this retrieval plan is thwarted or disrupted by external influences, performance declines.

TRY IT OUT

This chapter has a number of ideas for research projects on memory. For many of these, you can simply create a list of 20 or so words and use these as your materials. When you generate these lists, try to keep the words similar in some way, such as all being from the same class of words (e.g., nouns or verbs), being similar in length (e.g., five to six letters long with two syllables), and so on. When you present the information to people, try to keep the presentation time constant in the different conditions. Typically, for word lists, people might see each word for about one to three seconds each (you could write each word on an index card or something). To encourage some forgetting, have people do a distractor task, such as solve three-digit math problems (294 + 603 = ?) for two minutes. Ideally you should have at least 12 participants for each of these tasks, with at least 12 people in each group if you decide to vary things in your experiment between groups. Now, with these basic ground rules, here are some things that you could do:

Test the difference between incidental and intentional learning: have one group of people (incidental) rate each word for pleasantness and another group (intentional) study each word, knowing that they will get a memory test later. After the distractor period, have people write down as many words as they can. People in the incidental learning condition should remember fewer words than those in the intentional learning condition.

Test the effectiveness of imagery by giving a list of words to two groups of people. Have one group (control) simply try to learn the words as effectively as possible. Have the other group (experimental) try to form mental images of each study word. After the distractor period, have people write down as many words as they can remember. People in the experimental (imagery) condition should remember more than people in the control condition.

To show the effectiveness of concreteness, have two groups of people. For one group, keeping everything else the same, give them a list of nouns for concrete objects (e.g., “truck”) and, for the other group, give them nouns for abstract concepts (e.g., “trust”). After the distractor period, have people write down as many words as they can remember. People in the concrete condition should remember more words than those in the abstract condition.

Recognition

During recall, people need to generate the information, at least in part. However, in some cases, people need only to identify something already in their environment as being familiar or old, and thus recognized, or as being unfamiliar or new, and thus unrecognized. **Recognition** is a process in which the contents of the environment are compared with the contents of memory. If there is a match, then recognition occurs; otherwise, it does not.

Methods. The simplest form of recognition testing is **old–new recognition**. In this method a person is given an item and is asked to indicate whether it is old or new. Memory is assessed based on the pattern of responses. This method simplifies the retrieval situation, making it easier to track and analyze. A great deal of information can be derived from such simple tasks. Sophisticated approaches can lead to penetrating insights into the contents and process of memory. EEG recordings show that when items are recognized there is an initial increase in synchronization of theta activity around the parietal lobe, followed by decreased synchronization in the upper and lower alpha bands around the temporal lobe (Burgess & Gruzelier, 2000).

For simple old–new responses, some accurately reflect memory but others involve a degree of uncertainty and are guesses. Suppose a memory test has 50 old items (to which people should respond “yes”) and 50 new items (to which people should respond “no”). Now suppose that one person, Amy, identified the 50 old items by correctly responding “yes” to them on a recognition memory test. If she also had no incorrect answers of responding “yes” to the new items, then it would seem that her memory was very accurate. However, now suppose that another person, Scott, also identified the 50 old items by responding “yes” to them. If that he also incorrectly responded “yes” to the 50 new items on the recognition memory tests, then it is clear that his memory is actually pretty poor and that he was guessing for the entire test. What is needed is a way to correct for guessing on a recognition test to provide a more accurate estimate of memory.

Before discussing ways to correct for guessing, we first identify the four basic kinds of responses people can make on a recognition test (see Figure 3.3). The first kind of response is if people *correctly* respond “yes” to a memory item that is old (learned before). This kind of response is called a **hit**. The second kind of response is if people *incorrectly* respond “yes” to a memory item that is new (not learned before). This kind of response is called a **false alarm**. The third kind of response is if people *incorrectly* respond “no” to a memory item that is old. This is called a **miss**. Finally, the last kind of response is if people *correctly* respond “no” to a memory item that is new. This kind is called a **correct rejection**.

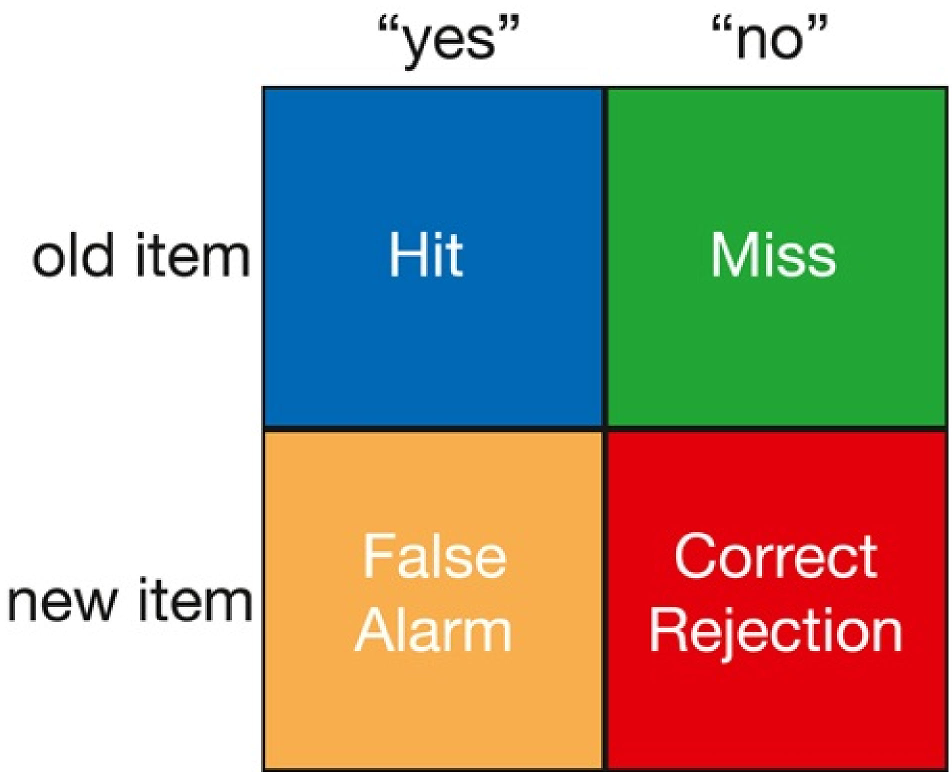

FIGURE 3.3 *Four Types of Possible Recognition Responses*

When correcting for guessing, you do not need to use the rate of responding for all four of these measures. If you take a minute and think about it, half of these are redundant with the other half. For example, if you know that a recognition memory test has 100 old items on it, and a person has 83 hits, then you immediately also know that they had 17 misses. Thus, the information in the hit and the miss rates are redundant. Similarly, if you know that there were 100 new items, and a person had 12 false alarms, you immediately know that they had 88 correct rejections. Thus, the information in the false alarm and correct rejection rates are redundant. As such, we only need two measures to assess performance. By convention, researchers use the hit and false alarm rates to correct for guessing.

A simple way to correct for guessing is to subtract the number of false alarms from the number of hits. However, this is a rather crude adjustment and it can miss some aspects of performance. Specifically, guessing on a recognition test can be affected by two pieces of information. One is the degree to which old items can be distinguished from new ones in memory. This is called **discrimination**. Sometimes discrimination is relatively easy, such as identifying whether a person is a famous actor or someone you’ve never heard of before. Other times it may be more difficult, such as identifying whether a person is a classmate of yours from 10 years ago or their twin sister.

The second piece of information is the degree to which people are willing to accept what is remembered as new or old. This is called **bias**. Sometimes people adopt a strict criterion and have a “conservative” bias. In this situation, people accept only cases in which they are very sure that the information is old so there are no false alarms. A situation in which people might be motivated to adopt a conservative bias would be in eyewitness identification. The eyewitness wants to be sure that the person identified is the criminal. Picking out the wrong person could lead to an innocent person being punished for a deed he or she did not commit and leaving the true guilty party at large, free to commit more crimes. In other cases, people may adopt a loose criterion and thus have a “liberal” bias. In this situation, people are more willing to accept a memory that has a more remote possibility of being old to avoid making any miss responses. A situation in which people might be motivated to adopt a liberal bias would be in looking for a lost set of keys. The searcher wants to be sure that all plausible locations are checked and the consequences resulting from a miss are fairly insignificant.

A method for estimating discrimination and bias is **signal detection theory** (Banks, 1970; Lockhart & Murdock, 1970). This approach has been adopted from psychophysicists studying sensation and perception, who, in turn, borrowed it from communications theory. By using this approach, one can derive a measure of discrimination, often called d’, and one of bias, often called ß (see Snodgrass & Corwin, 1988, for various measures of discrimination and bias).

The basic idea behind signal detection theory is to assess the ability to detect the signal (an accurate memory) from the noise (inaccurate memories). The thinking in signal detection theory is illustrated in Figure 3.4. This approach assumes that there are two distributions, one for the old items and one for the new items, along some dimension, such as familiarity. The further apart these two distributions are, the easier it is to discriminate between them. Conversely, the more these two distributions overlap, the harder it is to discriminate between them. Keeping the distance between the two distributions constant, we can see how bias affects memory performance. The criterion people use to separate out what is identified as old and new is measured by β. If β is set very far to the right, people have adopted a conservative criterion and very few memories will be accepted as old. However, if β is set far to the left, people have adopted a liberal criterion and very few memories will be accepted as new.

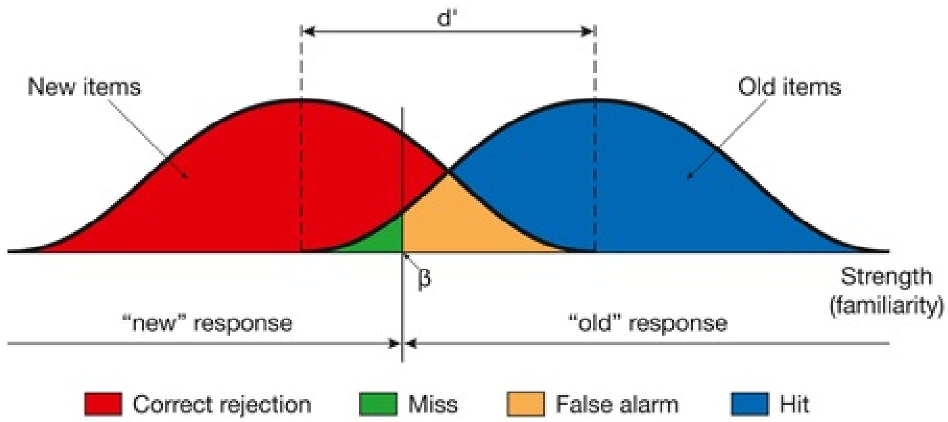

FIGURE 3.4 *Illustration of the Underlying Logic for Signal Detection Theory*

Another form of recognition is when people are given several items and are asked to indicate which one is old. This is **forced choice recognition**. Typically, there are two, three, or four alternatives. Forced choice recognition allows a researcher to manipulate the incorrect items in terms of the degree to which they resemble the correct one. Such manipulations can provide insight into what kinds of knowledge people are using when remembering something. The wrong items that are more often selected as "old" would more closely match the information in memory, thus lending some insight into the contents of memory. In addition, when forced choice recognition is used, particularly when there are three or more choices, the rate of chance performance is lower than the 50% for old–new recognition.

Principles. The use of recall and recognition tests have revealed a number of things about human memory. This includes both insight into how well information is learned as well as how information is structured in memory. This section outlines some principles of memory that have been derived from using recall and recognition tests. These included the forgetting curve, overlearning, reminiscence, and hypermnesia.

Perhaps the clearest finding to come out of research using recall tests is that the more time that has passed, the less likely people will remember information. Or, to put it simply, people forget more as time passes. The way forgetting proceeds was one of the first things discovered. The pattern of data that has been observed is the **forgetting curve**, shown in Figure 3.5, although technically it does not show forgetting per se. Instead what it is showing is the amount of information retained over time. As such, it can also be called a **retention curve**.

PHOTO 3.3 *Much of what we know about memory comes from having people take recall and recognition tests for the critical material at hand*

Source: LuckyBusiness/iStock/Thinkstock

A forgetting curve is a negatively accelerating function. That is, most of the forgetting occurs right after the information was learned. Research has shown that the forgetting curve follows a power function (Wixted & Ebbesen, 1991). However, it is unclear whether this is because of some fundamental neurological process or because of some artifact of averaging across many trials (Anderson & Tweney, 1997; Averell & Heathcote, 2011). For example, rather than a power function, the decay of individual traces may be more exponential, much as is observed in the physical world, as with the radiative decay of an isotope. Careful work suggests that individual memory traces are forgotten at an exponential rate but the averaging across them is best fit by a power function (Murre & Chessa, 2011).

As time passes, although the cumulative amount of forgetting loss grows larger, the rate of forgetting slows down accordingly. In other words, the rate of forgetting captured in the power function grows smaller and smaller. This change in the forgetting function is captured by **Jost's Law** (1897, as cited in Wixted, 2004), shown in Figure 3.6. Jost's Law is that, for memories of a similar strength, older memories decay more slowly than newer memories. Another way of stating this principle is that the rate of forgetting is not constant but slows down as the memories become older (and not yet forgotten). If memories were forgotten at a constant rate this should not happen. Yet, it does. Why might this be? A plausible idea is that, over time, while some memories are forgotten and lost, other memories are being consolidated and so are less likely to be forgotten. When memories are consolidated they are taken out of the pool of memories that could be forgotten. Thus, while there is a certain probability that memories in the unconsolidated memory pool may be forgotten, this pool is also shrinking because some memories are consolidated and so are likely to be more permanent.

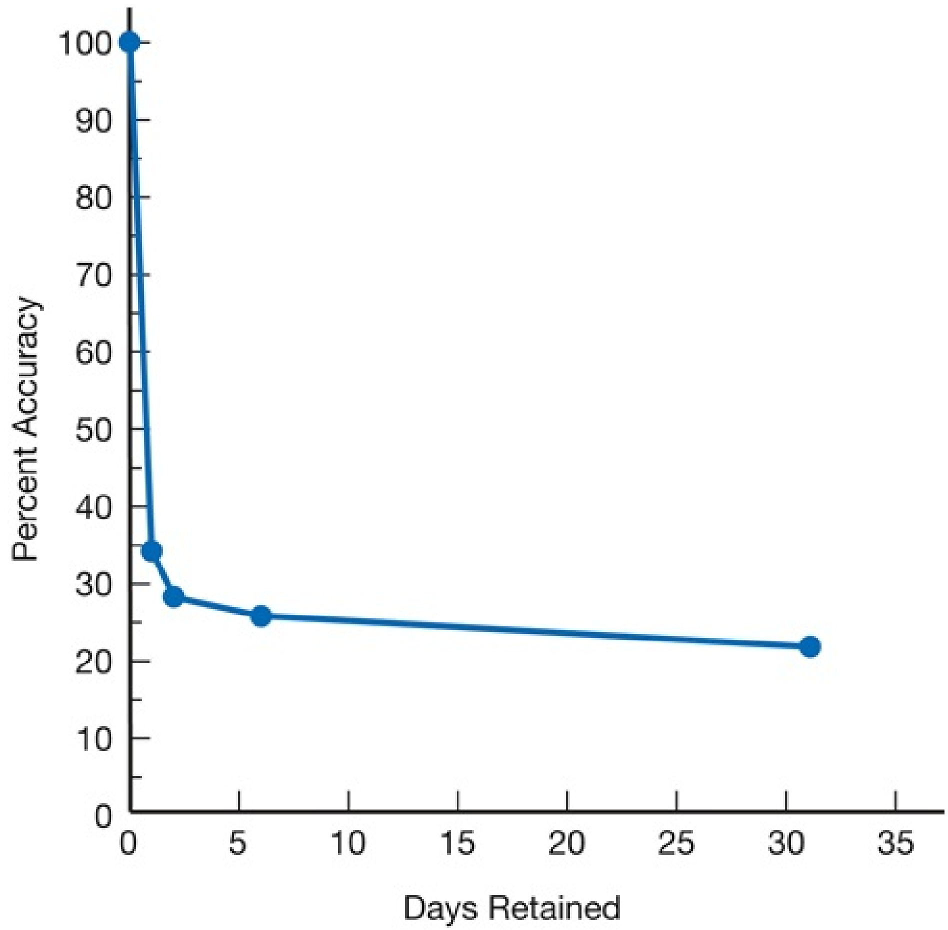

FIGURE 3.5 *Ebbinghaus's Forgetting Curve*

Plot of data reported in: Ebbinghaus, H. (1885/1964). *Memory: A Contribution to Experimental Psychology*. Translated by H. A. Ruger & C. E. Bussenius. New York: Dover 1.0

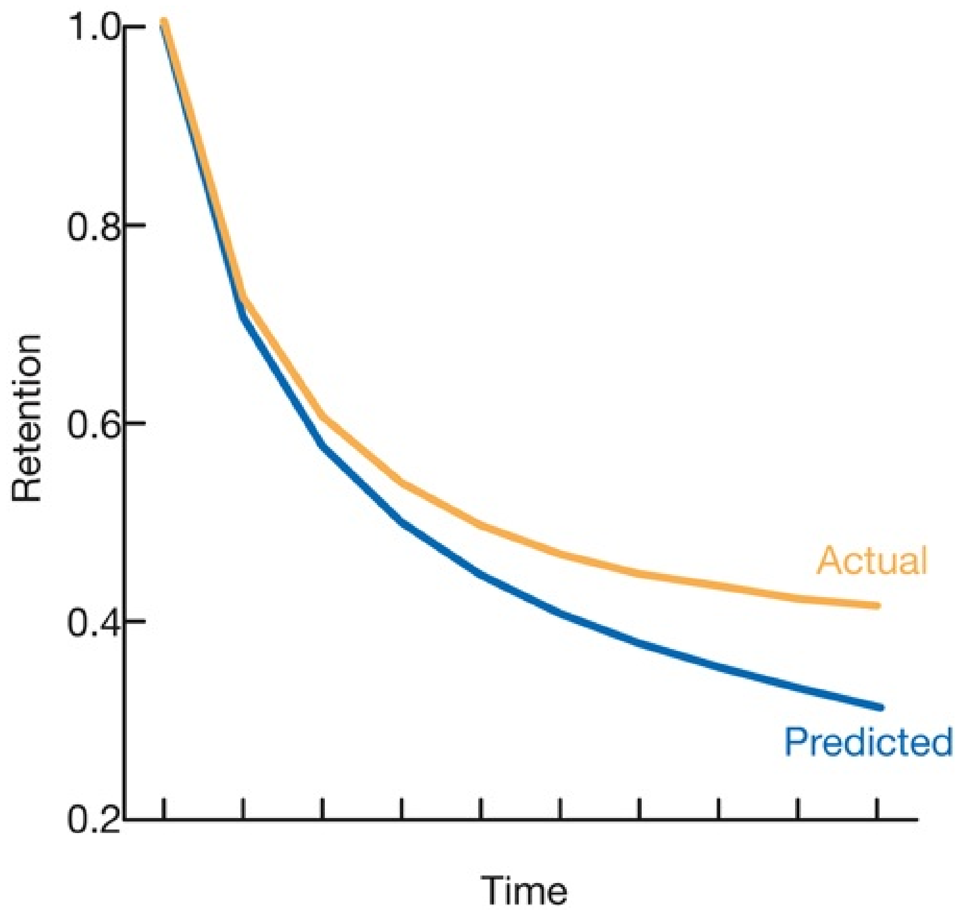

FIGURE 3.6 *Illustration of Jost's Law, in Which an Older Memory is Forgotten at a Slower Rate than a Newer Memory*

The forgetting curve is reassuring in its stability. Yet, at the same time, it is deeply disturbing in its suggestion that everything we've ever learned or known is fated to be forgotten at some point. While there is a truth in the forgetting curve, it is not always the case that forgetting inevitably occurs. Another principle that Ebbinghaus discovered using recall was overlearning. **Overlearning** occurs when people continue to study information after it is already possible to recall it without errors. This continued practice causes the forgetting curve to lessen and possibly disappear altogether. In such cases, the information becomes chronically available and is resistant to forgetting. Thus, many of the fundamentals you remember from your schooling, such as the "A, B, C" song, have been greatly overlearned, and you are unlikely to forget that knowledge. This is one reason why education emphasizes repetition and practice.

Not only do we forget things, but we can also remember things that were once forgotten. This principle of remembering previously forgotten information is **reminiscence** (Ballard, 1913). Generally, reminiscence is observed with a recall task, particularly free recall. Although reminiscence can occur, so does forgetting. Thus, if the times that people try to remember are spread out, even though reminiscence may be occurring, people may be remembering less and less overall. That said, if people try to recall information several times in a row, the rate of reminiscence may be greater than the rate of forgetting. In such circumstances the person is cumu latively remembering more and more each time (Erdelyi & Becker, 1974). This increased memory over multiple attempts is called **hypermnesia** (the opposite of amnesia). Hypermnesia is difficult to observe. It is more likely to be seen with pictures (Payne, 1987) and with shorter intervals between recall tests (Wheeler & Roediger, 1992). It is also more evident in free and cued recall situations than with recognition (Otani & Hodge, 1991). Hypermnesia may occur because the pieces of information in a set that are recalled earlier can serve as cues to assist the retrieval of the information that was previously forgotten.

The existence and operation of reminiscence and hypermnesia has practical significance. When it seems that you have completely forgotten a piece of information, putting it out of your mind for a period of time may help you remember it later. Of course, as with any type of memory, the more elaborately you think about the information during learning, such as forming mental images, the more successful later attempts to remember will be, even for appearance of the effects if reminiscence and hypermnesia.

Stop and Review

The two most common ways to test memory are recall and recognition. Recall involves producing information. The most basic type of recall test is a free recall test, in which people report as much as they can remember. The data from free recall tests tells us things about memory based not only on what was recalled but also based on any intrusions that may occur and the order in which items are reported. To encourage people to report memories that they are not confident in, a forced recall task might be used. Finally, cued recall can be used to elicit memories in response to cues. This is a way of manipulating context and its influence on memory. Often people need a retrieval plan to organize their recalls efforts. The comparison to recall is recognition. The basic type of recognition test is old–new recognition, in which people indicate whether things were encountered before. When using recognition data, you need some way to correct for guessing, such as doing a signal detection analysis. Forced choice recognition can also be used. It has the advantage of allowing you to manipulate the nature of the distractors to reveal some aspects of memory. Recall and recognition tests have helped illustrate the principles of the forgetting curve, overlearning, reminiscence, and hypermnesia.

ASSESSING MEMORY STRUCTURE AND PROCESS

In this section we cover ways of looking at memory structure and the processes that are used in retrieval. The structure of memories refers to both the organization of multiple pieces of information within a single memory trace or across multiple memory traces. The processes of memory refer to the mental activities that a person engages in when trying to retrieve a piece of knowledge. Basically, *how* do we remember?

Mental Chronometry

A frequently used source of information in memory research is the speed of responding. The speed with which your mind does something is mental chronometry. In many cases, this **response time** is recorded in the order of milliseconds or seconds.[4] The idea is that faster response times reflect simpler memory processes and/or more familiar memories, whereas slower response times reflect more complex memory processes and/or more unfamiliar memories.

Methods. Response time is measured from the onset of some stimulus. For example, when asked to identify whether a series of faces has been seen before, the time will be recorded from the moment the picture was shown to the time a person responds. The time for any given memory is not very informative by itself. That time must be placed in some context of other times to understand whether it is fast or slow. While there are many variations on this idea, the use of response times can be classified into two broad categories, subtractive and additive factor logic, described below.

The first approach to mental chronometry is Donders's **subtractive factors logic**. This is outlined in Figure 3.7. The idea is to have at least two conditions that are identical except for the inclusion of one processing step. For example, both conditions include the same encoding (factor A) and response (factor B) processes. However, the condition of interest involves an extra step (factor X). After collecting the times, the time for the simpler process (A + B) is subtracted from the time for the more complex one (A + X + B). What is left over should be the time for the critical process. For example, in a simple condition one could have people indicate whether a picture of a face is old or new. In a more complex condition, people would indicate whether a picture of a face is old or new and whether the individual is living or dead. Based on subtractive factors logic, the difference between these two conditions reflects the time it takes to remember a person's current health status.

While subtractive factors logic is appealing, it has a number of problems. For one, it is unclear whether the process of interest is added in a way that does not disrupt or change other processes, and whether the process of interest occurs at a time when these other processes are not taking place. Another approach to mental chronometry is **additive factors logic**, developed by Sternberg (and Chapter 4). This approach is outlined in Figure 3.8. Rather than having two conditions that differ by the presence or absence of a mental stage, in additive factors logic the critical stage of interest (factor X) is always present. What varies is its degree of involvement—that is, how much of that process is added relative to a comparison condition. For example, it may be a stage that a person needs to go through many times or that it involves various numbers of memory traces. By looking at the differences between conditions, one can get an estimate of the influence of each increment of complexity. This approach is more likely to preserve a greater array of mental processes across conditions, making the comparison more reliable and meaningful.

Most studies use *mean* response times for different conditions to assess memory, and this works well in many contexts. That said, keep in mind that response times typically do not produce normal bell curve distributions. Instead, they are positively skewed, with long tails to the right for very long response times. There are approaches that take advantage of this nature of response time distributions. Response time distributions are a mixture of two underlying distributions (Balota & Yap, 2011). For reference, see Figure 3.9. One of the distributions is the normal bell curve, also known as a Gaussian distribution. The other is an exponential distribution that starts out high for fast response times and tapers off for longer response times. The observed response time distribution is an ex-Gaussian distribution that reflects these two components. Importantly, the Gaussian and exponential distributions may reflect different underlying memory processes. Statistical procedures can be done to provide estimates of these two distributions, providing greater insight into how memory works. For example, the Gaussian distribution may reflect the speed of initiating a memory process, whereas the exponential component reflects individual differences in working memory capacity. A drawback of this approach is that it requires a large number of observations to derive stable estimates of the two underlying distributions.

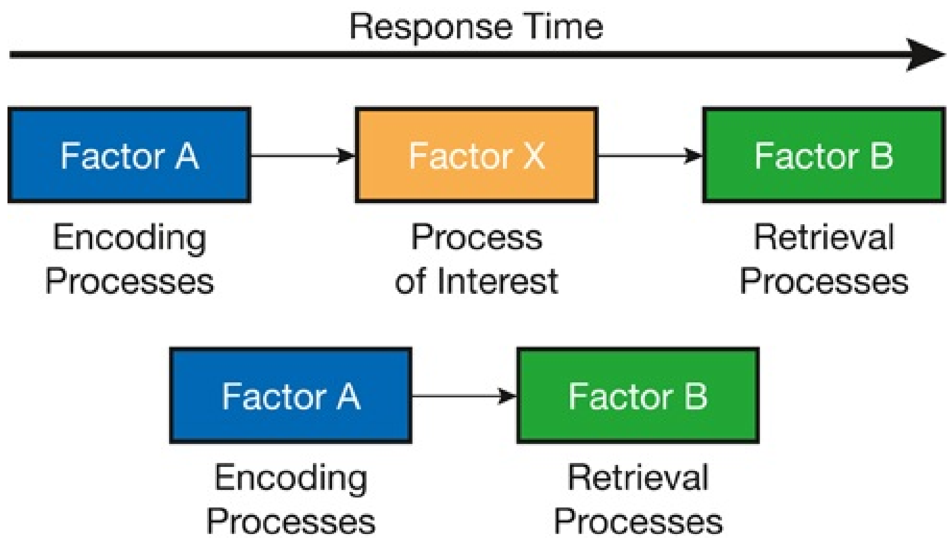

FIGURE 3.7 *Donders's Subtractive Factors Logic for Response Times*

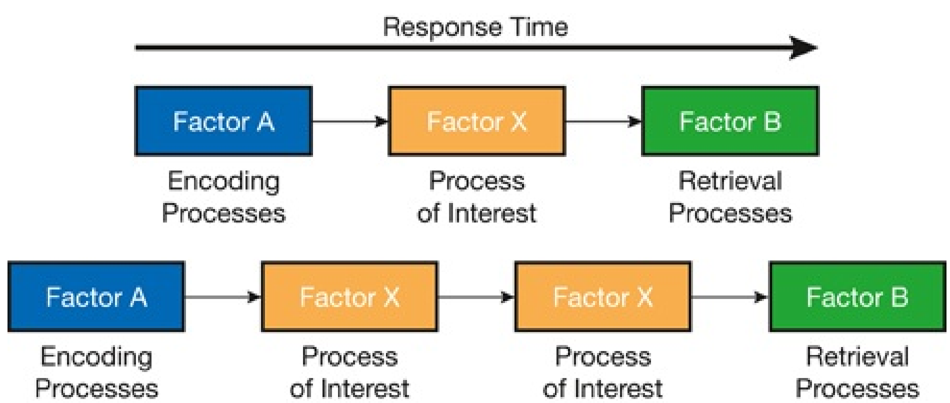

FIGURE 3.8 *Sternberg's Additive Factors Logic for Response Times*

Another point about response times is that most research involves some sort of manual response, such as pressing a button on a computer keyboard, screen, or mouse. Another primary source of response time data comes not from the hands but from the eyes, as with **eye tracking**. What eye-trackers do is tell the researcher what people are looking at and for how long. The time spent looking at something, called a fixation, can indicate whether something is stored in memory. For example, if you have already encountered something you are likely to spend less time looking at it than if you are seeing it for the first time.

In addition to tracking what the eyes are looking at, another eye-based methodology is **pupillometry**, which involves recording the size of a person's pupil and assessing how its size changes in different conditions. For example, pupils are larger when there is greater mental effort, such as when people need to remember more things (Goldinger & Papesh, 2012). Also, pupil size is larger during encoding for things that are better remembered later (Kafkas & Montaldi, 2011).

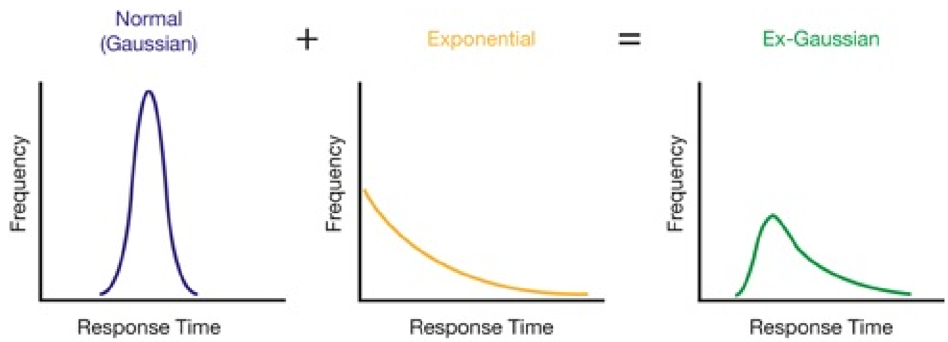

FIGURE 3.9 *Normal (Gaussian) and Exponential Distributions, Which can Combine to Form an Ex-Gaussian Distribution (This is the Form of Distribution Typically Observed in Response Time Studies)*

Principles. Response time data has yielded a wealth of information about memory. One of the most prominent principles is priming. Priming is a speedup in response time to items that immediately follow related items. For example, when making lexical decision judgments (that is, deciding whether a string of letters is a word or not), people are faster to say that the string "doctor" is a word if it immediately follows "nurse" than if it follows "bread" (Meyer & Schvaneveldt, 1971). The idea is that "nurse" activates or primes knowledge of nurses in long-term memory. The concept "doctor" is very related to "nurse," and so has been primed. So, information about doctors is retrieved faster than it would have been had the person just been thinking about something unrelated (like bread).

Cluster Analysis

Some methods are aimed at directly assessing how information is organized in memory. Knowing this can provide insight into how things such as remindings occur, and why our thoughts drift in some ways but not in others. There are a number of ways to approach this question. Data from priming studies is one way. Regardless of the method, what is going on is an attempt to look at clusters of memories. There is a special domain of statistics known as cluster analysis, in which the goal is to detect groups or clusters of information in a set of data.

Methods. There are number of clustering methods that can be used. An example of the output from a hypothetical cluster analysis of memory is shown in Figure 3.10. Here we focus on two relatively simple measures to give you a feel for how this approach works.

A time-based method for assessing memory organization with recall is if you track the amount of time between each recalled item. What you'll find is that there is not a uniform pattern. Instead, people report a burst of a few items, then a pause, then a burst of a few more, and a pause, and so on (Patterson, Meltzer, & Mandler, 1971). By using these **inter-item delays**, one can make inferences about memory structure. Memories that are structured together are likely to be recalled together during one of the bursts. However, information that is stored apart is more likely to be separated by a pause or delay.

STUDY IN DEPTH

An influential study of memory is Meyer and Schvaneveldt's (1971) study of semantic priming. The aim of this study was to assess whether the meaningfulness of the information in memory can influence the ease of retrieval of other information. To assess this, they used a paradigm that is a classic in memory research and which continues to be used to this day. This is the *lexical decision task*. For a lexical decision task, participants are presented with a series of letter strings. The task is simply to say whether the letter strings correspond to a word or not. So, for example, "doctor" is a word, but "ductyr" is not. Because people are often near perfect at this task, in terms of their accuracy, what is of importance here is the speed at which they respond. As such, response time, recorded in terms of milliseconds, is the critical dependent measure.

What Meyer and Schvaneveldt did was to test 12 high school students. They presented each student with a series of 240 letter string pairs, with each string being three to seven letters long. These 240 pairs were broken up in the following way: (1) 48 **nonword pairs**, such as "ductyr–prenct," (2) 96 **word–nonword pairs**, such as "krepst–office," (3) 48 pairs of **unrelated words**, such as "horse–butter," and, most importantly, (4) 48 pairs of **associated words**, such as "nurse–doctor."

After a brief practice period, the letter string pairs were presented, one pair at a time, on a screen. The letter strings were presented one on top of the other. People were told to respond by pressing one of two buttons, using one finger from each hand, as quickly and as accurately as possible. The right hand was used for “yes” if both of the letter strings were words, and the left hand for “no” if either or both were nonwords. Each pair was preceded by a ready signal so that people could prepare. After each trial, there was feedback indicating whether the response was correct or not. Each session lasted about 45 minutes.

After the data were collected, the response time data was analyzed considering only times for correct responses. For the (1) nonword pairs (M = 884 ms) and (2) word–nonword pairs (M = 996 ms), people were slightly slower, which is typical for negative “no” responses. This likely indicates extra processing taken to make sure that the letter strings were not words stored somewhere in memory. More importantly, people were slower to respond “yes” when the letter strings were (3) unrelated words (M = 940 ms) than if they were (4) associated word pairs (M = 855 ms). Thus, this shows that when people retrieve information from memory this is easier if the two memories are related than if they are not. One memory primes or facilitates the availability of those memories that are related to it. For example, in this case, the retrieval of the memory that “nurse” is a word spread to related memories about what a nurse is. As a result, the processing and retrieval of “doctor” was made easier and faster because the idea of *doctor* is highly related to the idea of *nurse*. That is, *nurse* primes *doctor*. Thus, we not only activate the memory we need at the moment, but we also activate other strongly related knowledge that may be useful, even if those memories are not completely retrieved.

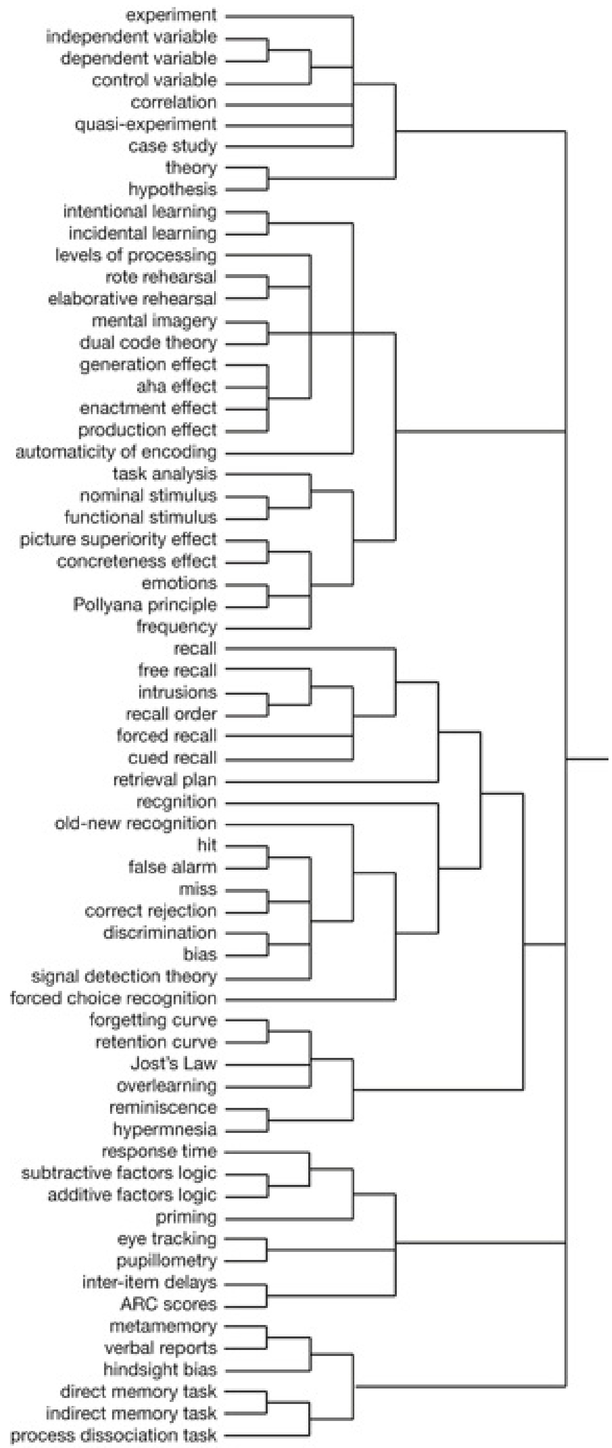

FIGURE 3.10 *Hypothetical Output From a Cluster Analysis. Note That Similar Concepts Are Clustered Closer Together, and More Distant Concepts Are Clustered Further Apart*

There are also ways of obtaining memory clusters by looking at the content of recall, specifically the order in which information was reported. Pieces of information that are stored together in memory are likely to be recalled together. In many cases you can make a reasonable guess about how a set of information could optimally be organized. For example, a set of words can be organized into categories. It then becomes possible to test whether people have adopted that organization. This can be done by calculating **Adjusted Ratio of Clustering** (or **ARC**) scores (Roenker, Thompson, & Brown, 1971). ARC scores index the degree to which a recall sequence conforms to predetermined categories, taking into account how much organization would be expected by chance. The formula for calculating ARC scores is given in the appendix. There are many sorts of analyses that address knowledge organization. For example, the **ARC'** score measures the degree to which a recall conforms to a sequential order (Pellegrino, 1971). The method for calculating ARC' scores is also provided in the appendix.

Apart from using more objective means of organizing information in memory, such as categories, it is also possible that people organize information in idiosyncratic and subjective ways. There are ways to get at subjective organization. This is useful when there is no clear *a priori* organization. One approach is a measure that produces an ordered cluster tree (Reitman & Rueter, 1980). Basically, people recall a complete set of information a number of times. What this measure does is look for consistencies in these repeated recalls, both in terms of the clusters that might be present as well as any stable sequential orders that might be produced.

Principles. Clustering methods have shown that memories are highly structured. This structure may take the form of a hierarchy. The more structure people can impose on information, the better their recall will be (Mandler, 1967). When people are given a set of information, they often adopt a hierarchical structure, which is seen in how they remember the information. For example, in a study by Bousfield (1953), students at the University of Connecticut were given a list of 60 words to memorize. These words were from four categories (animals, people's names, vegetables, and professions), but they were presented in a random order. When people later recalled the words there was a strong tendency to recall them in clusters based on the four categories. Moreover, as time passes and people have more experience with a set of information, their memories become more organized (e.g., Bousfield & Bousfield, 1966). In fact, experts in a domain have highly organized knowledge bases.

Finally, even when given what appears to be a random set of information, people impose some subjective organization upon it (Tulving, 1962). This subjective organization takes into account the idiosyncratic interpretations that people place on a set of items to create a structure that helps them remember.

While space may abhor a vacuum, the human brain abhors randomness. It is always searching for regularities and structure.

Stop and Review

There are number of ways to assess memory structure and function. Mental chronometry (response times) is a popular way to study memory. Priming is a classic example of the use of mental chronometry to explore memory. While the subtractive factors logic is one way to do this, some form of additive factors logic is a more common approach. With enough observations, more complex analyses can be done on the normal and exponential components of response time distributions. Memory structure and organization can also be assessed using eye movements and pupillometry to index changes in mental effort. Cluster analyses convey more directly how some types of knowledge are organized in memory. These analyses can be done using the gaps in time that occur during recall by evaluating which items tend to be recalled together or simply asking people to put items together in some way.

CONSCIOUS EXPERIENCE OF MEMORY

Metamemory Measures

Another important characteristic to consider is the phenomenological experience of memory. What does it feel like to remember? How do you know if you know something or not? The awareness of one's own memory and memory processes is **metamemory** and is highlighted in Chapter 15. A brief coverage of metamemory issues is presented here to illustrate how to study the experience and awareness of memory.

Methods. Metamemory studies ask people to report their own memory pro cesses. The method of introspection has a long and checkered past dating back to the early days of experimental psychology, and some people are still cautious about using such verbal reports (Nisbett & Wilson, 1977) because many of our mental processes lie outside of conscious awareness. However, despite this, there are still cases where verbal reports can provide insights about cognition (Ericsson & Simon, 1980), especially if one is concerned with the conscious experience of mental states and their consequences.

There are a number of metamemory methods. A common one is *remember* versus *know* judgments (Gardiner, 1988). With this approach, people are asked to recall or recognize a set of information. For those things that are recalled or identified as old, people then rate whether the information is something they consciously remember learning or something they know they encountered before but have no conscious memory of learning. For example, if you can recollect where and when you learned of your acceptance into college, then you would say that you remember it. In contrast, if you have no conscious memory of this event but you know it must have occurred, then you would say that you only know it.

Principles. A number of insights have been gained by looking at what people attribute to their own memory processes. People can be led astray and become biased when assessing their own memories. This is illustrated by the hindsight bias (Fischhoff, 1975). The hindsight bias is a tendency to distort memories so that they conform to one's current goals, circumstances, or knowledge. For example, people might be asked to make predictions about how likely an event is to occur, such as which team will win a football game and by how much. Then, at some time afterward, one group (the experimental group) is presented with information about the actual outcome. Another group (the control group) is not given this information. If everyone then is asked to report their original estimates, those in the experimental group are more likely to "misremember" their original estimates as being closer to the actual outcome. This is also one of the reasons why students may sometimes feel that they did not learn much during a class. They forget their prior ignorance and are not aware of just how much they have learned. We'll discuss this more in Chapter 15.

Implicit Memory

Again, implicit memory refers to memories and memory processes that are unconscious. It is rare that memory uses only implicit or explicit processes. Performance almost always reflects a mixture of the two. However, there are methods that allow for the influence of each of these to be separated.

Methods. Measures that are aimed more at implicit memory use tasks in which people are not aware that memory is being tested, or when there is little to no conscious control over the process. In general, it is difficult, if not impossible, to have a memory task that purely taps either implicit or explicit memory. As such, memory tasks are referred to as either direct memory tasks, which directly ask a person for a memory report (such as recall and recognition), or indirect memory tasks, which assess memory by focusing on a person's attention on another aspect of the task. In general, direct memory tasks involve more explicit memory, whereas indirect memory tasks involve more implicit memory. Indirect memory methods often either tap into pre-existing knowledge or present people with information and test memory some time afterward. In the latter case, the memory tests are given under the guise of being unrelated to what had been done previously so that people are not motivated to consciously remember. Indirect memory measures include such things as word fragment completion, perceptual identification, and priming.

As an example of an indirect memory test, suppose that in the first part of a study people are asked to rate a series of words for pleasantness. Then, after they have finished, the experimenter thanks them and says that because they still have some time left they will do another, unrelated study. At this point the experimenter might give a series of word fragments with the task of having the participants complete them with the first word that comes to mind. The researcher can then assess how often people completed the word fragments with words that had been seen before as compared to a group of people who had not seen those words previously. The difference reflects the operation of implicit memories of the previously seen words from the first part of the study.

One method for separating out implicit and explicit memory processes is the **process dissociation procedure**. This procedure can help estimate the relative influence of implicit and explicit memory process (Jacoby, 1991; Yonelinas & Jacoby, 2012). For example, suppose a person has read a list words and then takes a word fragment completion test. This process dissociation procedure works by having people recall information under two conditions. In the *inclusion* condition, people complete a series of word fragments with whatever words they can think of, even if they were from the prior list. In the *exclusion* condition, people uses any word they can think of, so long as they are *not* words that were on the previous list. Using performance in these two conditions, it is possible to get estimates of explicit and implicit memory. The procedures for calculating these components are given in the appendix.

Stop and Review

It is important to know what it consciously feels like to remember and what we consciously know we remember. The awareness of your own memory is metamemory. Metamemory studies reveal how accurate or inaccurate our insights into our own memories are. An example of a metamemory measure are remember–know judgments. Metamemory studies have revealed phenomena such as the hindsight bias. Many memory processes occur outside of conscious awareness, involving implicit memory. To assess how it works, you need clever methods that minimize or separate out conscious influences on remembering.

This involves using indirect tests of memory or using a process dissociation procedure.

PUTTING IT ALL TOGETHER

This chapter covered several methods for assessing memory and some basic principles that they illustrate. Each has its strengths and limitations. Memory is a slippery and ethereal thing that is difficult to gasp. Moreover, our intimate use of it makes it hard to get an objective look at just what memory is and how it works. The use of scientific methods of experiments, correlational studies, quasi-experiments, and case studies allows a more objective perspective. From the data gathered from these approaches you can better derive principles, theories, hypotheses, and predictions about the limits and capabilities of human memory. The conscious introspection into memories is only appropriate for exploring conscious experiences of memory, as with metamemory measures.

Using the methods and approach of scientific psychology, we have already discovered a wide range of principles about memory. We now know that the effort put into intentional learning can lead to better memory. This is seen with the various forms of deep processing, such as using mental images, generating information, the “aha” effect, the enactment effect, and the production effect. That said, memory is not influenced simply by the effort you put into it. Some types of materials are more automatically learned, and effort does not improve that. This knowledge is picked up even incidentally. Even when some effort is required, some things are learned more easily than others, such as pictures, concrete ideas, and emotional experiences. Moreover, the ease of learning is greatly influenced by whether you’ve ever encountered something before. In such cases, even if you feel that you’ve forgotten everything, there are some savings.

To get at what is in memory, you need to draw it out. This can be done directly using recall and recognition, with their various accuracy, intrusion, and response time measures. Alternatively, this can be done indirectly using measures such as fragment completion, eye tracking, and pupillometry. Each of these has variants and twists to let you get at this or that view on what is going on in memory. Moreover, each of these has also its limitations and some corrections may need to be made, such as taking into account any guessing. Also, there is always more information in memory that a given test will reveal. Although memory performance follows Ebbinghaus’s forgetting curve, which can be attenuated through overlearning, there are things that are forgotten that may later be remembered, as revealed by the principles of reminiscence and hypermnesia. Finally, memory is always seeking ways to structure and organize information to make it easier to remember. That organization may come from the materials themselves or be subjectively imposed.

To gain the most accurate picture of memory, it is important to use multiple methods and converging operations. The more methods that point to the same answer, the better that answer will be. However, if different methods lead to different answers, then something may be wrong in a study. For example, suppose people are more accurate and slower in one condition of a study than the other. This is a **speed–accuracy tradeoff** and is a problem for understanding memory. Because people are making fewer errors and slowing down, it may just be that they are being more careful. The data may not reflect anything about memory per se. Converging operations with a variety of methods gives us the greatest level of certainty about our discoveries.

STUDY QUESTIONS

1. What is an experiment? What are the primary components of an experiment? Why is experimentation a preferred way to study memory?
2. What are others ways to study memory besides experiments? What are their advantages and disadvantages?
3. What are theories and hypotheses and how do they relate to one another?
4. What are some ways to learn information so it will be better remembered later? Is this true of all kinds of information?
5. What kinds of information are easier to remember? What kinds are more difficult?
6. What is the difference between recall and recognition tests of memory?
7. What are the various sorts of recall tests and what can they reveal about memory?
8. What are the various sorts of recognition tests and what can they reveal about memory?
9. What are some of the ways to correct for guessing on memory tests?
10. What is the nature of the forgetting curve? How is it modified by aspects such as Jost’s Law?
11. How can mental chronometry be used to assess characteristics of memory? What is an example of some phenomenon of memory that is clearly shown using mental chronometry?
12. How can we use changes in a person’s eyes to assess memory?

13. How are cluster analyses used to study memory?
14. What is metamemory and what does it tell us about how people use their memories?
15. What is implicit memory and why is it important to memory functioning more generally?

KEY TERMS

- additive factors logic
- Adjusted Ratio of Clustering (ARC)
- “aha” effect
- associated words
- automaticity of encoding
- bias
- case study
- concreteness effect
- control variable
- correct rejection
- correlation
- cued recall
- dependent variable
- direct memory task
- discrimination
- dual code theory
- elaborative rehearsal
- emotions
- enactment effect
- experiment
- eye tracking
- false alarm
- forced recall
- forced choice recognition
- forgetting curve
- free recall
- frequency
- functional stimulus

- generation effect
- hindsight bias
- hit
- hypermnesia
- hypothesis
- incidental learning
- independent variable
- indirect memory task
- intentional learning
- inter-item delays
- intrusions
- Jost's Law
- levels of processing
- mental imagery
- metamemory
- miss
- nominal stimulus
- nonword pairs
- old-new recognition
- overlearning
- picture superiority effect
- Pollyanna principle
- priming
- process dissociation procedure
- production effect
- pupillometry
- quasi-experiment
- recall
- recall order
- recognition
- reminiscence
- response time
- retention curve
- retrieval plan
- rote rehearsal
- savings
- signal detection theory
- speed-accuracy tradeoff
- subtractive factors logic

- task analysis
- theory
- unrelated words
- verbal reports
- word-nonword pairs

EXPLORE MORE

Here are some additional readings to help you to explore more about some of the basic principles of memory.

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NOTES

1 What you would find is that people who study consistently score higher than people who cram.

2 See Blake, Nazarian, and Castel (2015) for a replication of this finding with the Apple logo, and Vendetti, Castel, and Holyoak (2013) for memory of frequently used elevator buttons.

3 See Crutcher and Beer (2011) for an auditory analog to the picture superiority effect.

4 Some researchers use the term **reaction time** rather than **response time**. However, following Luce (1986), the term response time is preferred. As Luce states, "response time is a generic term and reaction time refers only to experiments in which response time is made a major focus of attention for the subject. The experimenter may request the subject to respond as fast as possible, or to maintain the response times in a certain temporal interval, and so on" (p. 2). Thus, "reaction time" is for when a person makes a response as quickly as possible when a stimulus appears, and "response time" more generally, as is the case for all of the studies reported here.

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PART 2

Core Memory Topics

CHAPTER 4

Sensory and Short-Term Memory

When people think about memory, they typically think about retaining knowledge over long periods of time. When people speak of short-term memory, they often refer to remembering over a few hours or days. However, for many cognitive scientists, memory in the short term means much briefer spans of time, often less than a minute. What is the point of studying such fleeting memories? Aren't changes in the world from one moment to the next rather trivial? Well, no. Without these short-term memories, we would live in the permanent, absolute present—the eternal now. Language as we know it would not be possible. You would not be able to watch a film. Much of the world involves events that are spread out over time. Take the example of hearing a word. If you think about it, all words are made up of strings of sounds that are occurring at different points in time. To hear this string as a whole word, you need to integrate the sounds together. What allows you to do this is the memory of what occurred before, so the information you remember over time helps you link together the sounds to form the whole word.

Two types of brief memories are considered here. The first are very short-term memories, known as the sensory registers. These modality-specific systems allow us to do important sensory identification and integration, such as the preceding example of word identification. The second is what is more formally known as short-term memory. This type of memory stores ideas that are within or close to conscious awareness.

SENSORY MEMORY

The briefest memory systems are the **sensory registers**. These are modality-specific, such that each one retains information specific to a sensory modality. For example, the visual sensory register retains visual information. These are relatively primitive memory systems. Their primary purpose is low-level processing that involves the sensory information itself. Because different sensory systems process information with different properties, each sensory register has different qualities and characteristics. Some consideration is given here to three sensory registers: (1) visual sensory register, or iconic memory; (2) the auditory sensory register, or echoic memory; and (3) the haptic sensory register for touch information. There are others, but these three provide a relatively broad understanding of the sensory registers. The first two have been given a great deal of study. The third has received less attention, but it is included to illustrate how a sensory register operates even in a modality for which humans are not particularly well suited.

ICONIC MEMORY

The first sensory register considered is the visual sensory register or **iconic memory**. Humans are primarily visual animals. As such, iconic memory is the most extensively studied sensory register. Information is represented in iconic memory in a form that captures visual stimulation from our retinas, although there are some important differences. The mental representation in iconic memory is called an **icon** (hence the name *iconic* memory). To understand the role that iconic memory plays, we need to understand how much information is held in iconic memory, how long an iconic representation is retained, and how iconic information is used to build up mental representation of the visual world, even though at any moment we only see a small bit of it.

Span and Duration of Iconic Memory

The first two issues addressed here concerning the visual sensory register memory are how much information iconic memory can hold, and how long it can hold it. In one study, Averbach (1963) presented two people (himself and another) with sets of one to 13 dots for brief periods of time, anywhere from 40 to 600 milliseconds. The task was to say how many dots were in the display. The results are shown in Figure 4.1. For the briefest display (40 ms), people were fairly accurate when there was one dot, but they were pretty lousy when there were more than one. For the longer two durations (150 and 600 ms), they were fairly accurate when there were up to four or five dots, with performance declining gradually after that. Although there is a large time difference between the second and third conditions, the pattern of performance is roughly the same. The additional time did not provide much benefit.

Because this study looked at briefly presented displays, it is assessing iconic memory. From these data it is tempting to conclude that the amount of information held in iconic memory is four or five items. Any more is beyond a person's capacity. Within that range, people can make an accurate assessment of how many items are present. However, this is an incorrect conclusion. In a study by Sperling (1960), people were shown brief displays, similar to the Averbach (1963) study. People saw displays of letters instead of dots, and there were always 12 of them (in a 3 × 4 matrix). The task was to recall as many letters as possible. This display was presented for 50 milliseconds. In the control condition (also called the *whole report* condition), Sperling had people report as many of the letters as possible. In this case, people were able to name four or five. Again, by itself, this could be interpreted as showing that the number of items in iconic memory is four or five.

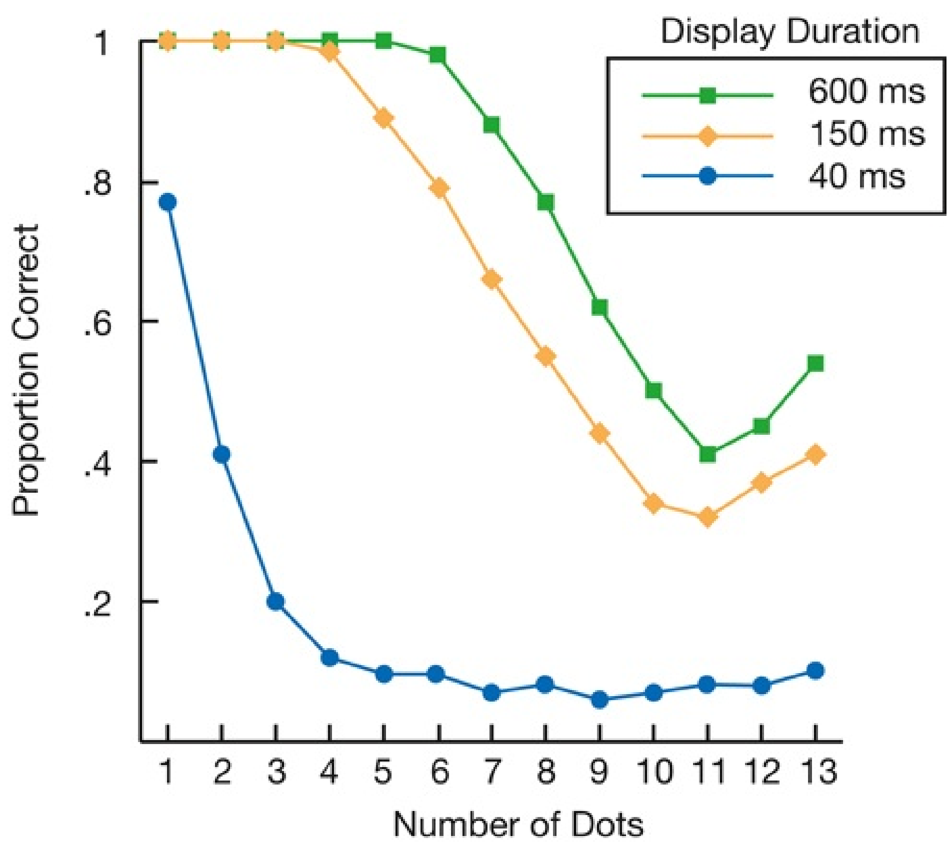

FIGURE 4.1 *Span of Apprehension Averaged Across Participants*

Adapted from: Averbach, E. (1963). The span of apprehension as a function of exposure duration. *Journal of Verbal Learning and Verbal Behavior, 2,* 60–64

PHOTO 4.1 *Rapid visual stimuli, such as lightning strikes, appear to last longer that they are actually present in the world because of the persistence of the image in iconic memory*

Source: Evgeniy1/iStock/Thinkstock

However, there was an experimental condition in Sperling's (1960) study (also called the *partial report* condition). Here, one of three tones was sounded to indicate which row of the display people should report. A high tone indicated the top row, a medium tone was for the middle row, and a low tone was for the bottom row. Moreover, this tone occurred anywhere from just prior to the display being removed to one second after the display had disappeared. Sperling used the sum of the performance at each row to estimate how much information was initially available in iconic memory. If people could always report all four items in a cued row, this would indicate that all of the information was represented, but that it decayed quickly. Alternatively, if people could report all four items from the top row but very few, if any, from the other rows, this would suggest that iconic memory can hold only very few items.

The results of this study are shown in Figure 4.2. Performance was near ceiling (very close to perfect) when the tone cue was presented at the time the display was removed. However, as the amount of time increased before the tone, there was a decline in performance. Nearing the quarter-second mark (250 milliseconds), people approached performance in the whole report condition. This indicates that a large amount of information is held in iconic memory—

perhaps just about anything entering the visual system. However, iconic memory has a very brief duration. By about a quarter-second, nearly everything that was initially in iconic memory has decayed away. This decay is deterministic, not random, suggesting some influence of higher-order processes (Gold, Murray, Sekuler, Bennett, & Sekuler, 2005). Anything that is left was presumably transferred from iconic memory into short-term memory before it was lost.

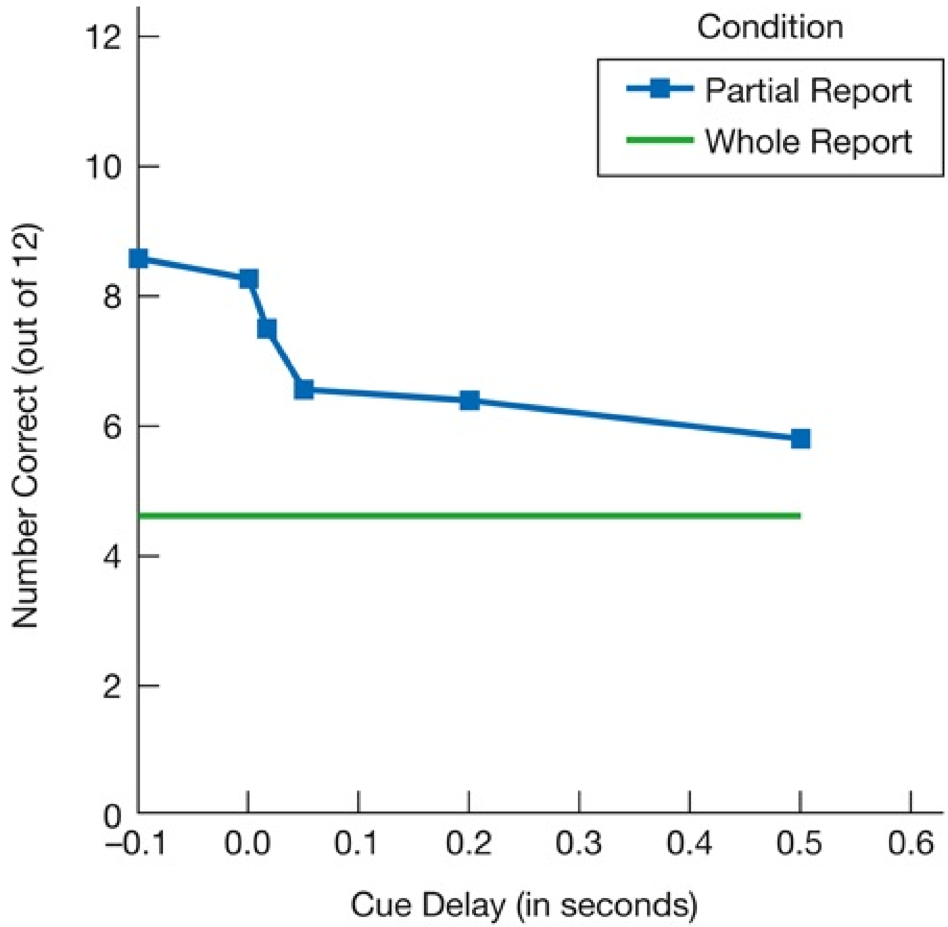

FIGURE 4.2 *Availability of Information in Iconic Memory*

Source: Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs: General and Applied*, *74*(11), 1–29

Anorthoscopic Perception

The effects of iconic memory can be observed in the distortions it produces. For example, a lightning strike appears to last longer than it actually does because we hold onto a memory of it. Another illustration is **anorthoscopic perception**, or the seeing-more-than-is-there phenomenon (Parks, 1965). This can be demonstrated by passing a picture behind a slit, as shown in Figure 4.3. If the figure is moved at a reasonably fast speed (e.g., 250–300 ms), people report seeing more of the figure than there actually is at any one point in time. This occurs because people are integrating information in iconic memory to reconstruct the shape of the object.

What also happens during anorthoscopic perception is that the iconic memory is compressed to accommodate all that was seen in a small region of space (McCloskey & Watkins, 1978). An example of this compression is shown in Figure 4.4. Furthermore, the faster the objects are moved behind the slit, the more compression there is (Haber & Nathanson, 1968). This is not the result of a retinal afterimage. If lots of visual information were presented to the same place on the retina, and people were using an afterimage of that, then it would all be jumbled into the same space on the retina and a perceptual blob would result. Instead, there is an active construction based on a memory of what was recently seen. There is a clear evolutionary advantage to having such a sensory register. Suppose you try to identify an object as it moves behind a cluster of branches. If you can quickly integrate the bits and pieces you are able to see, you can identify the creature more quickly. Is it lunch or a predator?

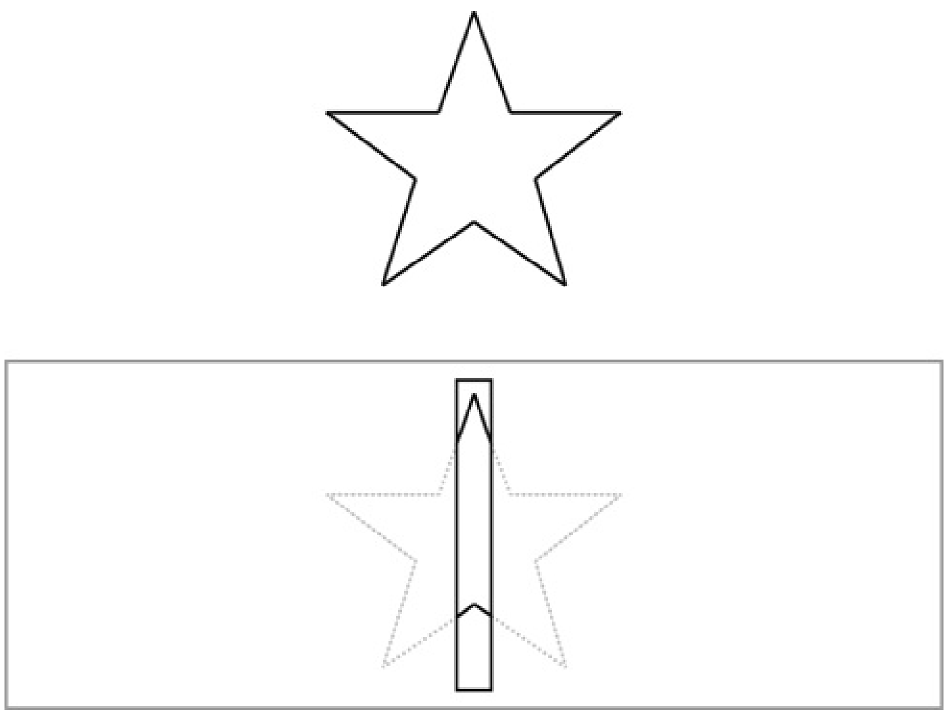

FIGURE 4.3 *Example of a Device Used to Illustrate Anorthoscopic Perception*

Adapted from: Haber, R. N., & Nathanson, L. S. (1968). Post-retinal storage? Some further observations on Parks' camel as seem through the eye of a needle. *Perception & Psychophysics*, 3, 349–355

FIGURE 4.4 *Example of Stimuli and Response Generated by People in the Study of Anorthoscopic Perception*

Adapted from: Haber, R. N., & Nathanson, L. S. (1968). Post-retinal storage? Some further observations on Parks' camel as seem through the eye of a needle. *Perception & Psychophysics, 3,* 349–355

Trans-Saccadic Memory

We do not view the world in one glance. Instead, we must move our eyes, head, and body to scan our surroundings. In doing so, we view different parts of the world and then integrate them to build a complete mental picture. A typical eye movement is called a **saccade**. When our eyes land on some point in space, it is called a **fixation**. Fixations typically last around 300 milliseconds and saccadic eye movements typically take about 30 ms to execute. Moreover, we mostly process information during the fixations. This characteristic of vision is important because it places demands on iconic memory. We need to integrate information across saccades to build up a picture of the world. There needs to be a **trans-saccadic memory** (see, e.g., Irwin, 1996) aspect of iconic memory to do this. There are a number of ideas about how this is done.

One idea was that trans-saccadic memory uses retinal coordinates, the position of an image on the retinas of your eyes. This makes sense in that iconic memory is a visual memory and the eyes provide the initial basis for this kind of information. However, this is incorrect. For example, suppose people are presented with two displays composed of portions of a 3 × 3 grid of eight dot locations. If the two grids were overlaid on top of one another, one could pick out the location of a missing ninth dot. This is easy to do when the two grids are presented in the same position and people do not have to move their eyes. The process of using this idea to test trans-saccadic memory is shown in the left column of Figure 4.5. The first display appears where people are currently looking. Then a cross appears in the periphery, indicating where people should look next. As people move their eyes to the new location, the first display is erased, and a second is presented where the eyes have moved to. This second display overlaps the first in retinal coordinates (that is, the same place on a person's eye). Under these conditions, people are *not* able to integrate these two displays to find the missing dot location. Thus, where images fall on the eyes does not appear to be important for trans-saccadic memory.

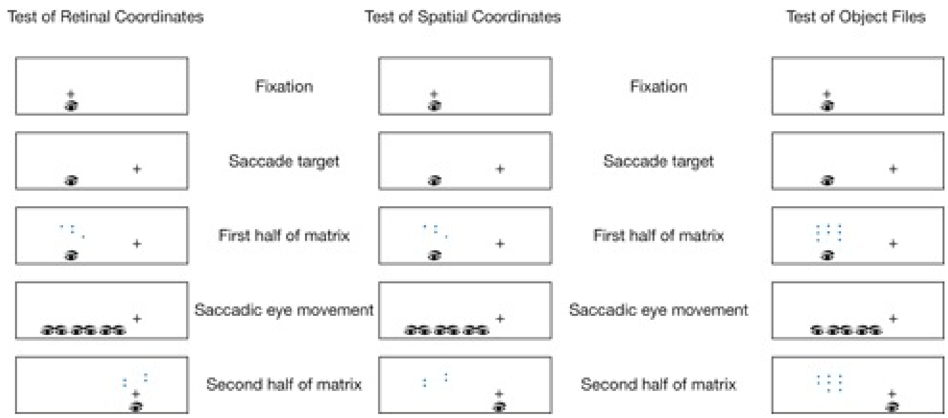

FIGURE 4.5 *Testing Retinally Based, Spatially Based, and Object-Based Ideas About Trans-Saccadic Memory*

Adapted from: Irwin, D. E., Brown, J. S., & Sun, J. S. (1988). Visual masking and visual integration across saccadic eye movements. *Journal of Experimental Psychology: General, 117*, 276–287

All right, does trans-saccadic memory use spatial information—that is, where things are in space? This makes sense in that people need to know how the world is structured beyond themselves. So, it could be that iconic memory uses information about where things are in space to build up an understanding of the world, similar to the way you could build up a larger picture by overlapping photographs taken from different positions. A similar procedure used to test the idea of retinally based integration can be used to test this idea. This is shown in the middle column of Figure 4.5, where the two dot patterns are in the same spatial location even though the eyes are in motion. However, this does not work either. People cannot perform well even though the two images are in the same spatial location (Irwin, Yantis, & Jonides, 1983).

Instead, what appears to be going on is that trans-saccadic memory uses representations of objects, called **object files** (Kahneman, Triesman, and Gibbs, 1992). That is, individual objects or entities serve as the basis for how we assemble our mental understanding of the visual world. Trans-saccadic memory does this by keeping track of basic characteristics of an object. Evidence for this comes from studies in which people are able to detect that something has been changed after an eye movement (Henderson & Anes, 1994). For example, in the right column of Figure 4.5, the task would require a response to indicate whether the dot pattern changed from one display to the next. This is a task that people can do quite readily. Moreover, change detection is more likely to occur when the entity is at the focus of attention rather than in the background. This suggests that although we subjectively experience the world as stable and full of detail, this impression relies in part on our memories to fill in the gaps with what we have seen before, or with what long-term memory assumes should be there.

Although trans-saccadic memory seems fairly simple, it can have important influences on more complex processing. That is, you can't do some kinds of thinking when your eyes are moving. For example, if people need to mentally rotate an image, such as an inverted sign (see Chapter 5), this takes longer if they have to concurrently make an eye movement (Irwin & Brockmole, 2000). The execution of an eye movement and active operation of trans-saccadic memory puts other memory processes on hold while the eyes are doing their thing. This may be because the same part of memory is needed to do both, and these two very simple cognitive operations, moving the eyes and mentally turning something, use the same underlying machinery.

Change Blindness

The lack of accurate detail in iconic memory has interesting consequences. For example, there are often errors in feature films that go unnoticed by most audience members, such as objects appearing and disappearing across cuts, clothes changing, and so on. These are called continuity errors. In a set of studies, people saw films in which objects changed across cuts. For example, dinner plates might change from red to white. However, people were very poor at detecting these changes and only did so less than 2% of the time (Levin & Simons, 1997).

In one study, people watched films in which one actor was changed across film cuts (the two people were of the same gender and ethnicity). Only 33% of the people noticed the change (Levin & Simons, 1997). In another example, an experimenter asked an individual (the subject) on the Cornell University campus for directions. While giving directions, two people passed between them carrying a door, thus blocking the subject's view of the experimenter. At this time, a second experimenter switched places with the first. After the door had passed, many people continued giving directions even though they were now talking to a different person. Only about 50% of the people noticed the switch (Simons & Levin, 1998).

Visual memory reflects our expectations. For briefly presented scenes, people are more likely to detect a change in an object if it belongs in the scene (e.g., a blender in a kitchen) than if it does not (e.g., a live chicken in a kitchen)

(Hollingworth & Henderson, 2003). This prior knowledge and expectation includes social constraints. In person-change experiments, college students were more likely to detect a person-switch when the experimenters were dressed like students than when they were dressed like construction workers. Students are in the same social group as the people being tested, but construction workers are not, so less attention is paid to them.

ECHOIC MEMORY

Echoic memory serves a similar purpose for audition as iconic memory does for vision. The mental representation in echoic memory is called the **echo**. However, because the demands on this system are different from vision, echoic memory differs in important ways. Specifically, echoic memory must take into account the fleeting and temporary nature of sound.

Span and Duration of Echoic Memory

As a parallel to iconic memory, let's look at the capacity and duration of echoic memory. In an analog to Sperling's (1960) study, Darwin, Turvey, and Crowder (1972) presented people wearing headphones with three lists of three digits. One list was presented only to the right ear, a second to only the left ear, and a third to both ears (so that it sounded like it was in the middle of the listener's head). Afterward, the person was asked to report as many of the digits as possible (whole report control condition) or to report only one of the lists based on a visual cue that indicated left, right, or middle list. The data from this study can be seen in Figure 4.6. As with Sperling's study of iconic memory, performance in the cued conditions indicated that more was available in echoic memory than was suggested by the whole report condition. Thus, echoic memory can retain a large amount of acoustic information.

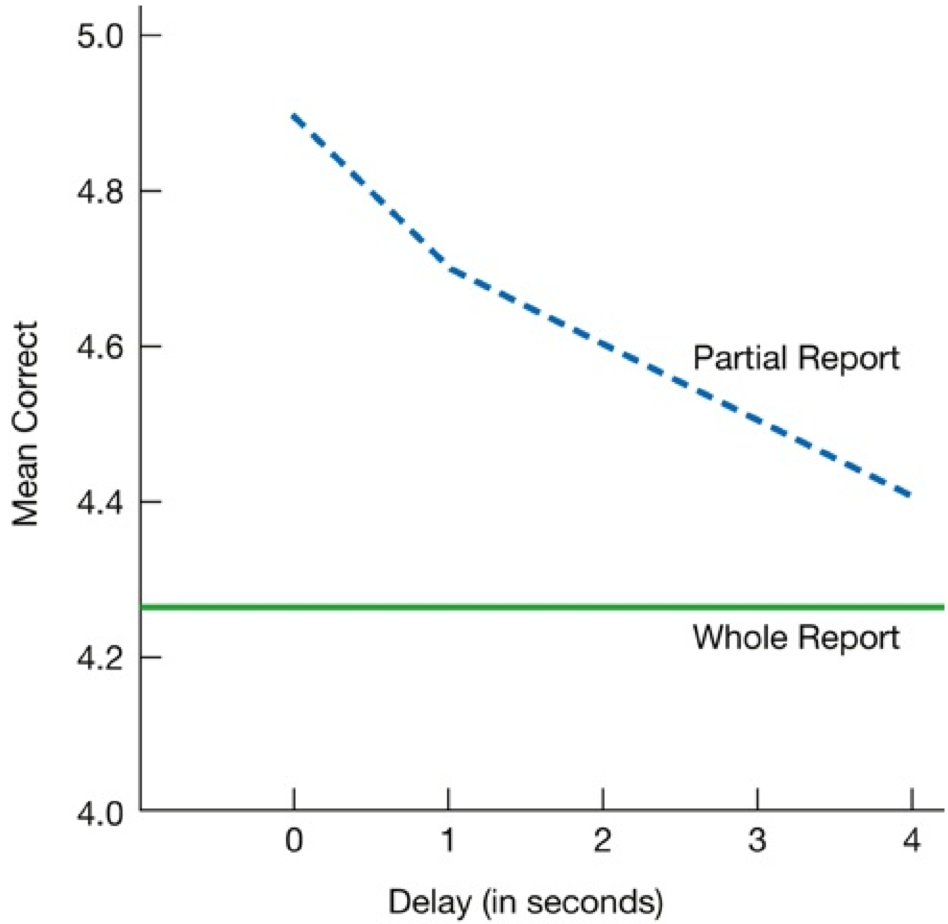

FIGURE 4.6 *Assessment of Echoic Memory*

Adapted from: Darwin, C. J., Turvey, M. T., & Crowder, R. G. (1972). An auditory analogue of the Sperling partial report procedure: Evidence for brief auditory storage. *Cognitive Psychology*, *3*, 255–267

Now consider the duration of echoic memory. As shown in Figure 4.6, unlike iconic memory, echoic information is retained for a longer period of time, about 4 seconds. This makes sense given the nature of auditory information. For vision, stuff in the environment is typically present all at once. Moreover, the eyes are constantly shifting to new locations, so old information must be removed to make way for the new. If people need to reprocess something, they need only to look at the thing again. In contrast, auditory information is stretched out over time and can typically be heard only once. As a consequence, echoic memory needs to keep larger chunks of information and retain it long enough so it can be properly analyzed to more accurately figure out what is being heard.

HAPTIC SENSORY MEMORY

While iconic and echoic memories have received the most attention, each sensory modality has its own memory store, with characteristics unique to it. For example, memory for touch, **haptic sensory memory**, must take into account qualities such as pressure and temperature. Moreover, it needs to account for both the spatial extent of what is in contact with the body and how it changes over time. Thus, this sensory register is more like iconic memory than echoic memory. Furthermore, different parts of the body are differentially sensitive to tactile information (e.g., the hands and face are more sensitive than the knees or back). Thus, the sensory register gives differential preference to touch information from different parts of the body.

Span and Duration of Haptic Sensory Memory

Let's look at the capacity and duration of haptic sensory memory. A study by Bliss, Crane, Mansfield, and Townsend (1966), also modeled on the Sperling (1960) study, had people receive small jets of air at different locations on the fingers of each hand. People gave whole reports of all of the locations that were stimulated or gave partial reports after a light or a tone to indicate which parts of the fingers were relevant. The results showed that in the whole report condition people could report three or four skin locations, but in the partial report condition performance was better, with people having access to nearly all of the locations. There was also a rapid decay of information such that by about 1.3 seconds much of the information was lost.

Stop and Review

Some kind of memory is needed for even brief periods of time, and each sensory modality has a sensory register dedicated to it. Iconic memory, the sensory register of vision, has a very large capacity but a very short duration, as was made clear from the work by Sperling and his partial report method. The integration of trans-saccadic visual information over time is done in a systematic, object-based way, and anorthoscopic perception reveals how people integrate object information when an image is passed behind an aperture. Finally, work on change blindness reveals that we are actively processing only small parts of the visual world. Echoic memory, the sensory register of hearing, also has a very large capacity and a short duration, although it holds on to information longer than iconic memory does, most likely because useful auditory information is stretched out over time. Haptic sensory memory also has a large capacity, but a short duration, and its processes are oriented toward the features of touch, such as pressure and spatial extent.

SHORT-TERM MEMORY

Short-term memory is responsible for processing and retaining information beyond the sensory registers, but not much longer than a minute or so (without active attention). Short-term memory is unique in that its contents include consciousness. So, when people are thinking, they are using information in short-term memory. We'll examine the active manipulation of information in Chapter 5 when we consider working memory.

Although it has been studied for years, the precise nature of short-term memory is still unclear. Some researchers think of short-term memory as a qualitatively different part of human memory. In contrast, others view short-term memory as just a portion of long-term memory that is currently active. For the latter view, there is no clear distinction between short- and long-term memory but a continuum of activity in a single memory system. Regardless of which view is closer to the truth, there are aspects of memory that are salient during short time periods. It is these aspects of memory that are of concern here.

Short-Term Memory Capacity

A striking aspect of short-term memory is its limited capacity. Only a small number of things can be actively held at once. This limited capacity is easily demonstrated. For a quick, at-home study, have a friend read you lists of random digits at the rate of about one per second. At the end of the list, recall the digits in the order that you heard them. Start with a short list, with only two or three digits, and then progress to longer lists. What you will find is that your short-term memory capacity is very small. Although this task starts out easy, it quickly becomes difficult. Most people are able to remember between five and nine digits in the correct order. In everyday experience you may run up against this limit if a person rattles off a telephone number too fast, or gives you a list of things to buy at the grocery store too quickly.

This small amount of information that can be held in short-term memory has been found for different types of information. A common idea is that a person's memory span is around seven items. The idea of short-term memory being an information processing bottleneck was first laid out in a classic paper entitled "The Magical Number Seven, Plus or Minus Two" (Miller, 1956[1]). Thus, memory span is often described as being seven plus or minus two chunks of information. The term *chunk* is important because what can serve as a unit of information is flexible.

Although this seven plus or minus two figure is often cited as the capacity of short-term memory, some researchers have argued that capacity is actually only about four plus or minus one items (Cowan, 2000). People remember more information because they are using other cognitive resources to extend the functional size of short-term memory. For example, people may chunk the information (see below) or use long-term memories to augment short-term memory.

Regardless of whether the capacity of short-term memory is seven or four units, this is still not a lot. Yet, we are capable of thinking about larger amounts of knowledge than this limit would imply. We can have rather complex thoughts during the course of a day. How do we do it? There are ways to expand short-term memory capacity. The most widely discussed is the concept of chunking. **Chunking** occurs when people take smaller units of information and group them into a larger unit. This functionally expands the capacity of short-term memory.

For example, if you were given a list of letters to remember, you may remember about seven of them. However, if those letters are grouped into words, then you can remember seven unrelated words and the number of letters that you remember increases. A word serves as a chunk to organize the letters. Every time there is an opportunity for chunking, there is an opportunity to hold more information in short-term memory. So when you are trying to learn something new, you are more likely to be able to retain it if you can place it into some organization or structure.

TRY IT OUT

In this chapter there are a number of ideas for research on the operation of short-term memory. In this Try It Out section we look at how to assess short-term memory capacity. Ideally you should have at least 12 participants for this task, with at least 12 people in each group if you decide to vary things in your own experiment between groups. Now, here is what you could do to assess short-term memory capacity. Give a group of people progressively larger, randomly ordered, sets of items to remember. These can be digits, letters, or even simple words. Start with relatively small sets of items, such as two, and work up to progressively larger set sizes, with five lists for each set size. Present each list one item at a time, with a one-second interval between items.

At the end of the list, the participant should write the items down in the order they were heard. If a person cannot get any of the lists correct at a given level (none of the five item lists), then you can stop. Afterward, score each person in terms of the highest level at which they could recall a list. If a person gets only one of the lists at the highest level score that level as a half. However, if they get two or more, give them full credit for that level. Most people should have a highest recall level between five and nine.

PHOTO 4.2 *If we can group lists of items, such as a list of items needed at the grocery store, into meaningful chunks, such at what to get in the produce section, bakery, canned goods, etc., then our memory for that information will be better*

Source: gpointstudio/iStock/Thinkstock

Improving Your Memory

To have better memory in the long run, it is best if your memory operates effectively in the short run. One of the most effective techniques for improving memory discussed here is the idea that chunking, or grouping information together into larger meaningful units, can improve short-term memory. That is, organize information by putting things together into groups. This can be based on some structure already present in the information (such as common categories, like produce, meat, and dairy), or by some structure that you make up for yourself. By doing this, you will remember more information overall. Moreover, this boost in remembering in the short term can benefit you in the long run as well. This is why creating an outline of what you are trying to learn can help. Thus, to improve your memory, look for ways to structure or organize sets of material. The more that you group together information in any way that makes sense to you, the faster that you will learn it and the more that you will remember.

So what guides chunking? Prior knowledge is a major influence. The more you know, the easier it is to form chunks by identifying patterns in information. The more knowledge you have, and the more efficient your application of that knowledge becomes, the greater your memory capacity will seem, even though it really stays about the same. Thus, memory can be improved by gaining expertise. So, expose yourself to a wide range of different kinds of experiences to improve your memory.

Very Large Capacity

The influence of expertise on short-term memory capacity is clearly seen in a study by Ericsson, Chase, and Faloon (1980). In this study at Carnegie Mellon University, they had a person, S. F., come to the memory lab to assess his short-term memory span for digits. At the beginning of the study his digit span was about seven items. They continued to test him for over a year and a half. As shown in Figure 4.7, over time his digit span grew larger and larger. At the end of the study he could repeat back, in the correct order, nearly 80 digits that he had just heard read to him at the rate of one per second. Note that each list was different each time. How did he achieve this superhuman feat of reaching such a large digit span?

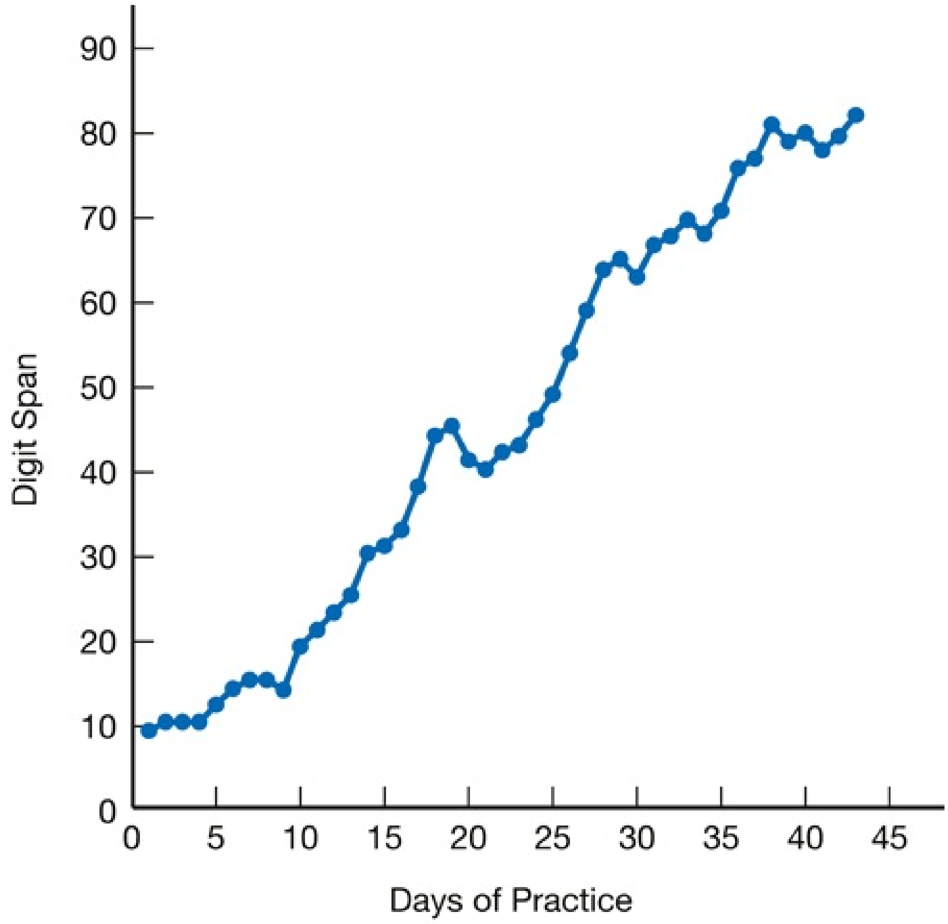

FIGURE 4.7 *Example of Expertise Influences on Short-Term Memory Span—In This Case, S. F.'s Digit Span Improved With Practice*

Source: Ericsson, K.A., Chase, W. G., & Faloon, S. (1980). Acquisition of a memory skill. *Science*, *208*, 1181–1182

Well, S. F. was a runner. He grouped the digits into chunks based on race lengths and running times, as well as using other devices, such as famous dates. For example, the sequence 3492 was recoded as "3 minutes, 49 point 2 seconds, near world-record mile time," and 1944 as "near the end of World War II." The increase in S. F.'s memory span was a result of his using long-term knowledge to organize information in his short-term memory. This made his short-term memory capacity seem larger. Note that his chunks were each often made up of three or four digits. The fact that S. F.'s short-term memory span, per se, did not actually grow larger is illustrated by the fact that, after his digit span had grown to gargantuan proportions, when he was given a set of letters his memory span dropped back down to six.

Another example of the influence of expertise is memory for chessboards. In one study, people were first given a picture of a chessboard with pieces arranged on it. This board was then removed and people reconstructed the positions of the pieces. Chess experts were much better at remembering where the pieces were on the board compared to people who are novice chess players. The chess experts were drawing on their knowledge of the game to help them chunk the pieces and thus remember their original locations. This is highlighted by conditions in which people were given chessboards that were not from the middle of a game but had pieces randomly placed on the board. In these circumstances, everyone's memory declined and the chess masters performed no better than the novices (Chase & Simon, 1973).

Another way that short-term memory capacity may be affected is if a person has **synesthesia**. People with synesthesia have involuntary sensory experiences in addition to normal ones (see Grossenbacher & Lovelace, 2001, and Hochel & Milán, 2008, for reviews). For example, a person may experience colors when reading words. Two likely causes of synesthesia are a decreased ability to sufficiently suppress inappropriate feedback loops in perception (Grossenbacher & Lovelace, 2001) or an incomplete pruning of cortical connections during development (Maurer, 1997). Accounts of the effects of synesthesia on memory began with Luria's (1968) subject, S. (see Chapter 15). He had a phenomenal verbatim memory, in part because he used his synesthetic experience as a memory aid. In general, synesthetes do better on short-term memory tests, such as memory for simple word lists (Radvansky, Gibson, & McNerney, 2011; Yaro & Ward, 2007). Synesthetes appear to use the additional sensory experiences that they have to help them retain and remember items in short-term memory.

Note that synesthesia does not uniformly improve memory. For example, if synesthetes and controls are given items to learn that are (1) printed in black, (2) colors congruent with their own synesthetic experience, or (3) colors incongruent with that experience, then synesthetes do better than the controls on memory for items presented in congruent colors but worse when the items were in incongruent colors (Smilek, Dixon, Cudahy, & Merikle, 2002; Radvansky et al., 2011). This suggests that synesthesia can impair memory when the synesthetic experience is inconsistent with the information in the world. Synesthetes also do not show a von Restorff effect (see Chapter 7) if the unique word in a list is identified by color (e.g., a red word among a list of black words) (Radvansky et al., 2011). Finally, it should be noted that synesthetes do not appear to be any better than normal at processing information beyond the individual word level, such as at the event model level of comprehension (Radvansky, Gibson, & McNerney, 2014). So, just because there are larger memory span scores does not necessarily lead to superior comprehension.

Duration of Short-Term Memory and Forgetting

Short-term memory is a bottleneck not only because of its small capacity; it also retains information, without active attention, for short periods of time. Without active attention, information in short-term memory is largely forgotten in 30 seconds. The trick in showing this is that a person must first think about something so that it enters short-term memory and then not think about it again until memory is tested.

There are a number of problems with this basic idea. First, it is next to impossible to tell people *not* to think about anything and have them do it (Wegner, 1989). People's minds are always drifting around searching for something, anything, to think about. Second, whatever thoughts they have cannot be related to what you are trying to test. Otherwise, they are attending to it and you cannot study how it is being forgotten.

There have been a number of attempts to account for short-term memory forgetting. The primary issue has been whether forgetting is due to a decay or an interference process. For **decay**, the primary cause of forgetting is the passage of time, or at least some process that is strongly correlated with time, like the decay of neural connections (Hardt, Nader, & Nadel, 2013). The more time that passes, the more the memory trace has decayed and forgetting has occurred. An early piece of evidence to support a decay interpretation was reported more or less simultaneously by Brown (1958) and by Peterson and Peterson (1959). As such, it is known as the Brown–Peterson paradigm.

In the Petersons' study, students at Indiana University at Bloomington were given consonant trigrams (e.g., TPZ) to remember. To keep students from actively rehearsing these, after seeing the trigram they gave the students a three-digit number (e.g., 274), with the task of saying the number aloud and then counting backward by threes (e.g., 274, 271, 268, 265) until they were told to stop, at which point they were to recall the trigram. This study varied the amount of time between the presentation of the trigram and the cue to recall the information. The data from this study is in Figure 4.8, which shows a nice forgetting curve. The more time that has elapsed, the less likely it was that the trigram was remembered. By 18 seconds, nearly all of the information was lost. Because the to-be-remembered information did not appear to be involved in the current stream of thought, the only mechanism that seemed a likely candidate for forgetting was decay.

While the decay theory has some intuitive appeal and is relatively simple (and science prefers simpler explanations), there are serious challenges to this idea.

Most of these challenges rest on the idea that forgetting is caused by interference. With **interference**, information in short-term memory interferes with or in some blocks, displaces, or otherwise hinders the retrieval of other information. Because short-term memory has a limited capacity, any new information put into it is likely to compete with the information that is already there.

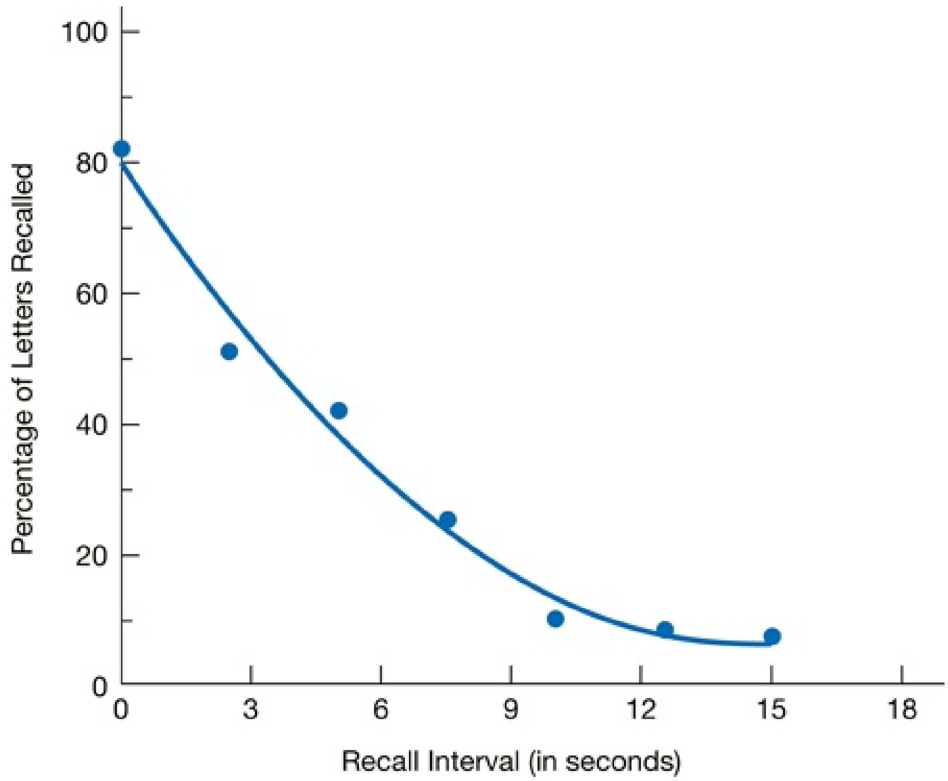

FIGURE 4.8 *Results from Peterson and Peterson's Short-Term Memory Experiment*

Source: Peterson, L. R., & Peterson, M. J. (1959). Short-term retention of individual verbal items. *Journal of Experimental Psychology, 58*, 193–198

One study that supported the interference idea was done by Keppel and Underwood (1962). They suggested that some of the forgetting in the Brown–Peterson paradigm was due to interference from items learned on previous trials. That is, the prior letter trigrams remained in memory and competed with the new trigrams, which were supposed to be remembered. What they did was to have only three trials in the entire experiment. With this approach, they found that there was virtually no forgetting on the first trial. Performance was essentially perfect. Forgetting only started to appear on the second and third trials. So, when there was no source of interference from prior trials in the task, there was no short-term memoryforgetting.

Another study was done by Waugh and Norman (1965). They gave people lists of 16 digits. At the end of each list was a probe digit, which was also marked with a tone. The task was to state what digit followed the earlier occurrence of the probe digit in the series that was just presented. In this way the experimenters could control how much interference people had experienced. The further back in the list the probe digit was, the more interference there was. To get at issues of decay, they presented the digits at either a slow rate (one per second) or a fast rate (four per second). The results are shown in Figure 4.9. The more intervening items between the probe and its prior occurrence—that is, the more interference there was—the greater the forgetting. The rate of forgetting is similar in both the slow and fast presentation conditions. Thus, short-term memory forgetting is more of a function of the amount of interference than the amount of time that has passed. Forgetting was observed in the Brown–Peterson studies because the task of counting backward produced interference and caused the forgetting of the trigrams.

In sum, interference is the primary cause of forgetting in short-term memory. That said, there are some memory scientists who argue that there is at least some involvement of decay (e.g., Berman, Jonides, & Lewis, 2009; Portrat, Barrouillet, & Camos, 2008; but also see Lewandowsky & Oberauer, 2009). Altmann and Schunn (2012) make a compelling argument that the classic Waugh and Norman (1965) data, which has been used to support an interference account of short-term memory forgetting, actually reflects a principled mixture of both decay and interference processes, with interference having a greater influence.

This forgetting of information through interference from new information entering short-term memory has implications for everyday life. For example, if you are trying to keep information in mind, such as a telephone number or a person's name, and are disrupted by something else, it is likely that you will forget it. When you are reading or listening to something, you may need to keep track of a number of ideas to understand what is being communicated. If you are not able to do so effectively, then your comprehension and your memory will suffer. In a study by Zeamer and Fox Tree (2013), students remembered less from a short lecture if there was additional distracting auditory information, such as audience laughter, murmuring, construction noises, and so on. So, to improve your memory, it is best to keep sources of interference to a minimum.

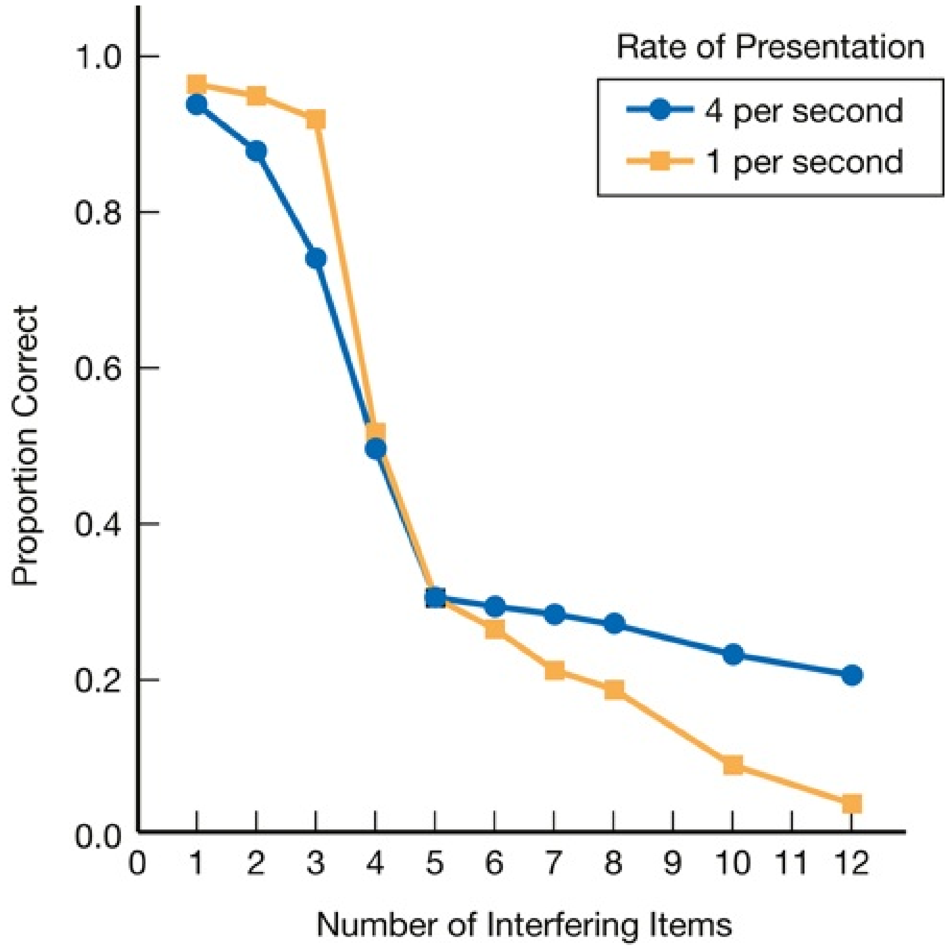

FIGURE 4.9 *Results from Waugh and Norman's Interference Experiment*

Source: Waugh, N. C., & Norman, D. A. (1965). Primary memory. *Psychological Review, 72*, 89–104

Overall, if there is interfering information in the environment during comprehension, this displaces the information that you need in short-term memory. If you try to study with the television on, your ability to understand and remember what you are studying is compromised. If you try to reason through something, you often need to consider various possibilities and outcomes. This places a strain on short-term memory. We have all been in situations in which there was a lot going on around us while we made a decision, and because we were not able to think clearly due to an interference we were left with a choice we later regretted.

Stop and Review

Short-term memory can hold only a small amount of information for a few seconds. We can increase our capacity by chunking information into larger units. When forgetting occurs, this is due to processes correlated with the passage of time, primarily the intrusion of new, interfering information that blocks, displaces, or otherwise hinders memory for the target information.

RETRIEVAL IN SHORT-TERM MEMORY

If a person encodes information into the limited capacity of short-term memory and avoids decay and interference sufficiently to retain it, it may be necessary to then use it. At that point it needs to be retrieved. For example, suppose you are on the phone with someone who tells you a list of names of people who will be attending a surprise party just as you are walking into a dining hall. There you see a friend, and now you need to remember if that person's name was in the set of people you just heard. Somehow, the contents of short-term memory must be searched to select the one item (that person's name) that is needed. How do you do this? As you can read in the Study in Depth box overleaf, it appears as though people are using a serial self-terminating search in which people search through items one at a time in short-term memory and produce a response after they have gotten through all of the items.

Serial Versus Parallel Issues

An important point about the search of short-term memory is that not everyone agrees that a serial process is involved here. There are other possibilities that Sternberg did not consider. It has been suggested that this pattern of data could result from parallel processing in which there are limited cognitive resources. When multiple elements are held in short-term memory, these resources are divided among them. This is like sending water down a pipe and then dividing the pipe into several smaller pipes, resulting in less water flowing down any one pipe. As a result, the more finely divided cognitive resources are, the less there is available to any one item and thus the longer it takes for retrieval to occur.

STUDY IN DEPTH

One of the most notable attempts to address the search of short-term memory was a series of studies by Sternberg (1966, 1969, 1975). In one of his studies (1966) he used an experimental paradigm in which eight students at the

University of Pennsylvania were given lists of one to six digits (e.g., 5, 2, 4, 3, 8, 0) to hold in short-term memory. These digits were presented one at a time, for 1.2 seconds each. Note that these list sizes are well within the capacity of short-term memory. At the end of the list, after a two-second delay, people were then given a memory probe (e.g., 4) with the task of pressing a button to indicate whether it was in the list. For a dependent measure, Sternberg recorded how long it took to respond as a function of how many items were in the set and whether the probe was in the set. There were 24 practice trials and 144 experimental trials, with half of each requiring a “yes” response and half “no.”

Using this approach Sternberg tested three theories of short-term memory search. The first is a **parallel search**, in which all of the items in short-term memory are available more or less at once, and accessed in parallel. This makes sense if one assumes that the contents of short-term memory are either in or close to consciousness. If people search short-term memory in parallel, then the amount of information in the search set should not matter. All of the information is available at once regardless of the size of the search set. As a result, response times should not vary with set size and there should be no difference between the “yes” and “no” responses.

A second alternative is a **serial self-terminating search**. This involves going through items one at a time, that is, in serial. Once people get to the target item, the search stops or terminates. In this type of search there is an increase in response time with an increase in set size. By going through the items one by one, the larger the set, the longer it should take. There is also a difference in the slope of the response times for “yes” and “no” responses. For “no” responses, the function is relatively steep because the person always needs to go through the entire set to verify that the probe item is not there. However, for “yes” responses, there is an increasing response time slope but it should be half that of “no” responses. This is because people are going through the items one at a time and on average they will get about halfway through the set before getting to the target item.

The final alternative is a **serial exhaustive search**. This again involves people going through things one at a time, in serial. However, rather than stopping when they got to what they were looking for, people would continue until they had gone through the entire set. This search process would also result in an increasing response time function with increasing set size. However, if people searched in a serial exhaustive fashion, there would be no difference in the response time slope for the “yes” and “no” responses. This is because in both cases people are going through the entire set of information.

The results of Sternberg's study are shown in Figure 4.10. As you can see, the data supports a serial exhaustive search. This outcome is instructive in two ways. First, it shows how short-term memory is searched. The other lesson here is about our ability to report on our own memory processes. When I list the three possible outcomes in my classes and ask students to state which one they think is true, most people pick serial self-terminating search. It may, in some way, be consistent with subjective experience. The fact that so many people get this wrong is important because we are talking about a simple process that occurs repeatedly throughout our lives in a portion of memory that is very close to conscious awareness. This is why memory researchers do so many studies trying to understand what may sometimes seem like a simple question to answer. It is not unusual for the results of experiments to produce counterintuitive results. We do not have much conscious awareness of how our own memories operate. We need objective measures to test our theories.

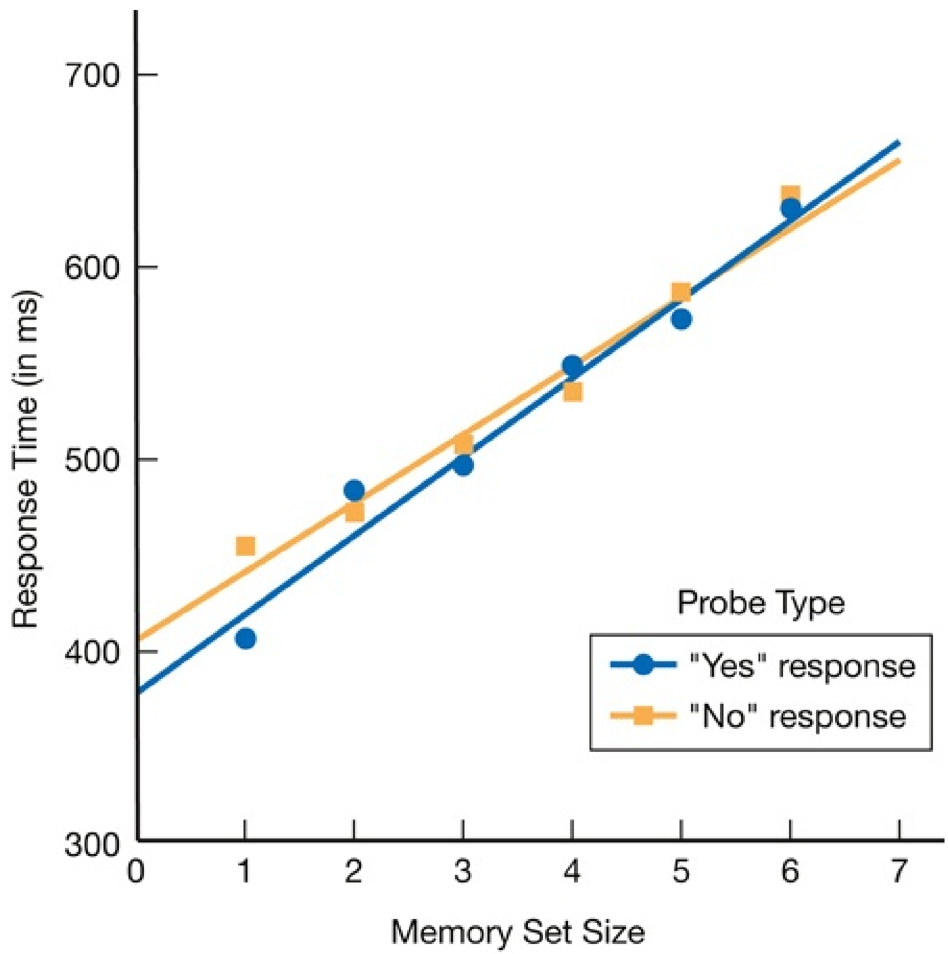

FIGURE 4.10 *Results of Sternberg's Search of Short-Term Memory Task*

Source: Sternberg, S. (1966). High-speed scanning in human memory. *Science, 153*, 652–654

This issue of serial versus parallel process has a long and tortuous history in memory research (Townsend, 1990). It is not unusual for one researcher to claim that a given memory process is either serial or parallel and then to have another researcher come along and demonstrate that the opposite could be true. Currently, it is generally accepted that, for any process, both serial and parallel processes can be derived to produce a given outcome. Thus, it is difficult to distinguish between the two, so researchers select the one that seems more plausible and/or the simpler.

For every complex memory process there are probably both parallel and serial components intermixed in **cascading processes**. The brain is composed of billions of neurons that are all regularly engaged in some sort of processing. Thus, because several neural assemblies are often simultaneously being used for memory, there is some element of parallel processing. For example, when people try to remember where they heard something they need to know both what the information is and the source of the information. Memory processes can also involve stages in which latter steps simply cannot be done without the results of other, earlier steps.

Serial Position Curves

We now consider temporal influences on the retrieval of information from short-term memory. One of the most durable short-term memory effects is the **serial position curve**, shown in Figure 4.11 (Rundus, 1971). It has been studied at least since the early work of Mary Whiton Calkins in the late nineteenth century (Madigan & O'Hara, 1992). A serial position curve is a U-shaped function, with memory being better for information at the beginning and end of a set, whereas information in the middle is less well remembered (Murdock, 1962). This serial position curve is found for various information types and set sizes.

The superior memory for information at the beginning of a set is the **primacy effect**. Traditionally, the primacy effect is not a short-term memory effect per se but is attributed to long-term memory. The idea is that items at the beginning of a set have more opportunity to be rehearsed and are more likely to have been consolidated into long-term memory. For example, for the first item, no other items have been given yet, so all of the rehearsal effort can be devoted to it. As such, the first item has the highest probability of being transferred to long-term memory. For the second item, attention is now split between the first and second items, so it is less likely that the second item will make it to long-term memory. This logic can then be extended to the rest of the list. After a number of items, the amount of additional rehearsal benefit is negligible. The relationship between practice and later memory for items is also shown in Figure 4.11. Rundus (1971) tracked how much each item was rehearsed by having people say their rehearsals aloud during learning. As you can see, for the primacy effect, the more rehearsals of a given item, the more likely it was remembered later.

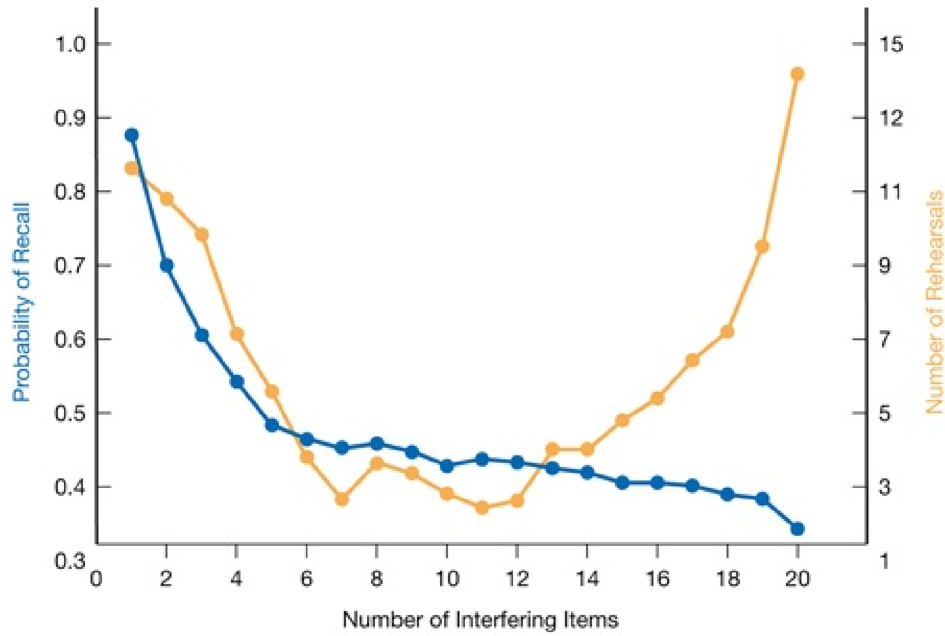

FIGURE 4.11 *A Standard Serial Position Curve in Short-Term Memory. Blue Dots Show Short-Term Memory and Gold Dots Indicate the Mean Number of Rehearsals per Item*

Source: Rundus, D. (1971). Analysis of rehearsal processes in free recall. *Journal of Experimental Psychology, 89*, 63–77

If people are given more time to rehearse information, then the primacy effect gets larger. The predicted pattern of results is shown in Figure 4.12, with single, double, and triple referring to the amount of time a person had to study each item. This prediction was confirmed in a study by Glanzer and Cunitz (1966) in which people were given information at different speeds. When the presentation rate was slow, memory was better and the primacy effect was larger, but the recency effect was unaffected. The idea that the primacy effect depends more on long-term memory is further supported by fMRI data showing that early items (primacy effect) involve more activation of brain areas associated with long-term verbal memory, such as the left hippocampus and parts of the left temporal lobe

(BA 36), whereas late items (recency effect) show increased activation of parietal lobe areas, such as the right inferior portions (BAs 39 & 40) (Talmi, Grady, Goshen-Gottstein, & Moscovitch, 2005).

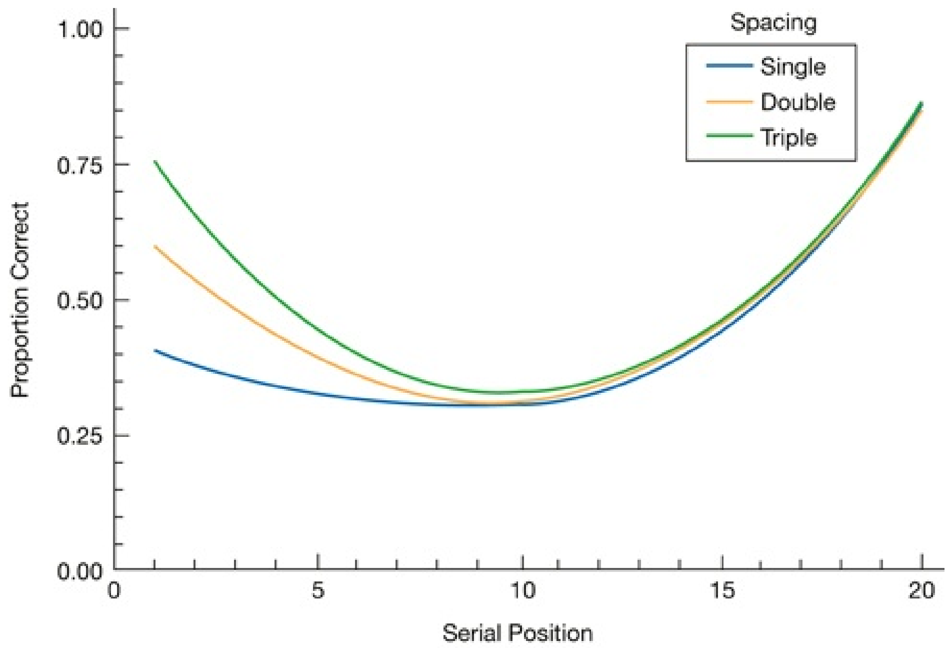

FIGURE 4.12 *Effects of Additional Rehearsal Time on the Primacy Effect*

The other half of the serial position curve is superior memory for items at the end of the set, which is the **recency effect**. The recency effect is attributed to short-term memory (Davelaar, Goshen-Gottstein, Ashkenazi, Haarmann, & Usher, 2005). These items have not been displaced by later interfering information and so are less likely to be forgotten. In Rundus's (1971) study, the later items are not rehearsed as much. These items are remembered not because of how much they were rehearsed but because they are likely to still be in short-term memory. So, to maximize performance, it is best to try to recall the most recent things first, before you encounter potentially interfering information, and then move to whatever is stored in long-term memory. This is illustrated in Figure 4.13, in which there are various retention intervals that are filled with a distractor task to displace information from short-term memory. Glanzer and Cunitz's (1966) study confirmed this aspect of the serial position curve. In a second experiment, people waited a period of time, during which they did a distractor task, before they recalled the information. The longer the filled delay at the end of the list, the less pronounced the recency effect. However, the primacy portion of the curve, which is attributed to long-term memory, was unaffected.

Changing the Serial Position Curve

While the serial position curve is a robust finding, it is not always observed. There are things that can reduce the primacy or recency effect or eliminate them altogether. We'll look at examples of each. Most research on serial position curves uses verbal materials, such as lists of words. In comparison, in terms of memories for recently performed actions, although performed actions are remembered better than words (see Chapter 3), there is still some forgetting. Again, this is the enactment effect. This forgetting is influenced by serial position, but with performed actions there is no primacy effect (Seiler & Engelkamp, 2003). Doing something leads a person to focus more attention on the individual actions. As such, there is less opportunity to rehearse those that were done previously, and so this information is less likely to be transferred to long-term memory. As a result, no primacy effect is seen for performed actions.

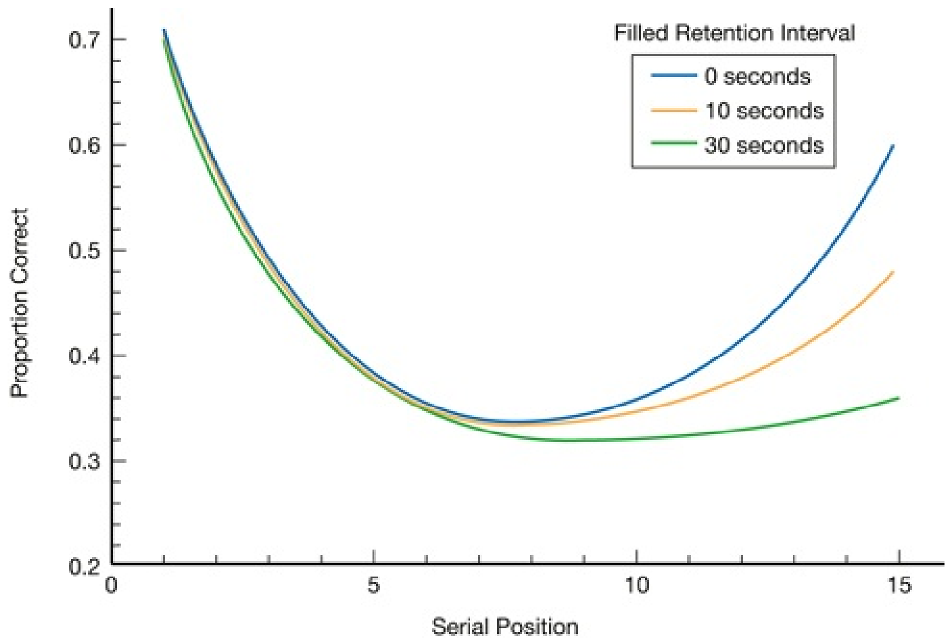

FIGURE 4.13 *Effects of Different Filled Retention Intervals (in Seconds) on the Recency Effect*

TRY IT OUT

The storage of information in short-term memory is affected by the order in which the items were encountered. This is clear when one looks at serial position curves for information beyond the capacity of short-term memory. To demonstrate serial position curves (see Zechmeister & Nyberg, 1982), first assemble a list of 15–20 single-syllable words. These are the words that you will be reading to your participants.

After you have done this, gather 12 or more people to be your participants. Give each person a piece of paper on which to write their responses. Have them listen while you read aloud your list of 15–20 words. Read these words clearly at a rate of about one word per second. At the end of the list, have your participants write down as many of these words as they can remember. For this task, the order in which they write them down is of less importance, but that is something that you can manipulate if you want to. You should give people about five minutes to recall as much as they can remember.

After the participants are done recalling, collect their response sheets. Then you should tabulate which words were recalled as a function of the order in which they appeared on the list. What you should find is that people remember more from the beginning and end of the list but fewer from the middle. You can do a number of variations of this by altering list lengths, by giving a second group of people a 30-second distractor task of math problems (e.g., 935 + 135 =?) at the end (to eliminate the recency effect), or by having people verbalize their rehearsals to see the relationship of these with the primacy effect.

Also, when people are given a sequence of odors they show a strong recency effect but only a weak or absent primacy effect (Miles & Hodder, 2005). In general, items that are difficult to name, such as what something smells like, tend to show recency effects but not primacy effects, because it is harder to encode them into declarative long-term memory. This suggests that the primacy effect, as it is typically measured, depends critically on the ability to effectively and quickly store information in long-term memory.

Another serial position phenomenon is the **suffix effect**. With the suffix effect, the recency effect is diminished when extra information is presented at the end of a list (Conrad, 1960; Crowder & Morton, 1969). For example, suppose you heard a list of words in a short-term memory study. Then, at the end of the list, the experimenter either said nothing or said the word “go” to indicate that you should recall the list. In this case, the word “go” is a suffix. Memory is worse in the “go” condition than in the silence condition. The word “go” interferes with information in short-term memory, causing forgetting. As a real-world illustration of the suffix effect, Schilling and Weaver (1983) had students call a telephone operator to request a phone number. After giving the number, when the operator concluded the call with the phrase “Have a nice day” memory for the phone number that was just heard was worse. The pleasantry at the end served as a suffix, causing more forgetting of the target information (the phone number).

The size of the suffix effect is related to the nature of the suffix itself. The more it is like the items on a list, the greater the interference and the greater the suffix effect (Ayers et al., 1979). As illustrated in Figure 4.14, when the suffix was human speech, the recency effect was reduced, but not when it was an unrelated sound, such as a buzzer. It is also important what the person thinks the suffix is. When people hear a list of words and then hear a “baa” sound, if they are told that the sound was made by a person there is a larger suffix effect than if they are told it was made by a sheep, even though the same sound is used (Neath, Surprenant, & Crowder, 1993).

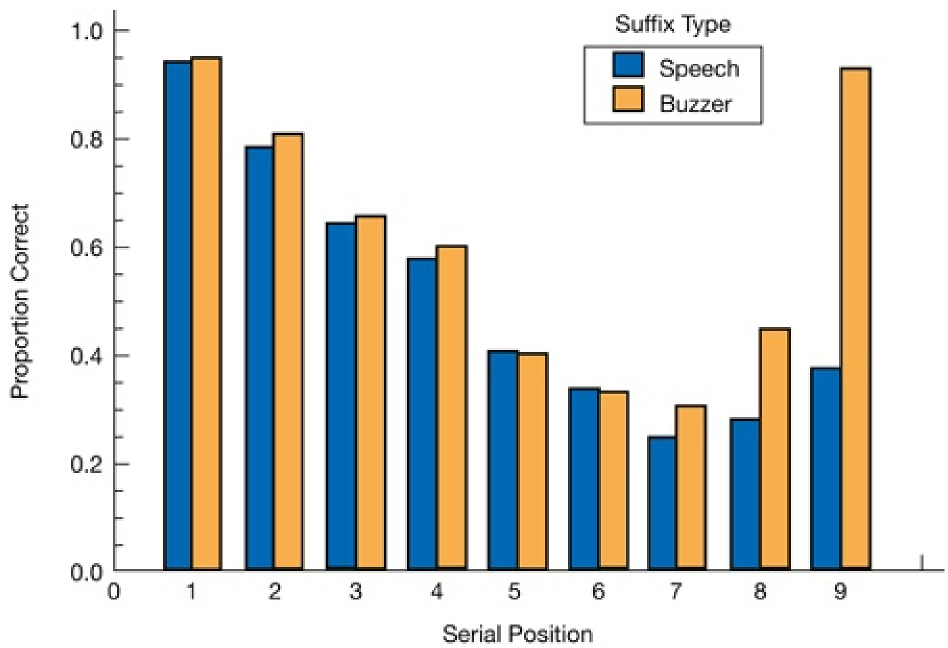

FIGURE 4.14 *Suffix Effects with Human Speech and Nonhuman Nonspeech Sound*

Adapted from: Crowder, R. G. (1972). Visual and auditory memory. In J. F. Kavanagh & I. G. Mattingly (Eds.), *Language by Ear and by Eye*. Cambridge, MA: MIT Press

In general, the suffix effect is influenced by the physical characteristics of a suffix, leading many researchers to consider it as part of echoic memory. This was hammered out in a marathon series of 15 experiments reported by Morton, Crowder, and Prussin (1971). They found that the suffix effect was unaffected by the meaning of the suffix or its frequency or emotionality. However, the effect was reduced if the suffix came from a different location in space, was in a different timbre (human voice versus noise), or was from a different person, particularly one of a different gender. Thus, the suffix effect is influenced not only by both perceptual qualities but also by a conceptual understanding of what is being heard (Bloom, 2006). Finally, the suffix effect can also occur for visual information, lip reading, tactile stimuli, and odors (Campbell & Dodd, 1982; Mahrer & Miles, 1999; Parmentier, Tremblay, & Jones, 2004). This presence of a suffix effect in all these sensory modalities suggests that it is a general property of short-term memory.

TRY IT OUT

The recency portion of the serial position curve reflects the idea that information that is still being held in short-term memory has not yet been displaced by new information. It should be possible to reduce or eliminate the recency effect by giving people other nonlist items after the last list item to produce a suffix effect. Before you do the study, set up 11 lists of digits (from 1 to 9) in which there are eight digits, in a random order, on each list. Make sure there are no repeats within a list, and that there are no sequential runs in a list (e.g., 7, 8, 9).

After you have your lists, you will need two groups of at least 12 people in each. Read aloud the list of digits. The task is for people to recall the digits, in the order they hear them, after the end of a list. They can write their responses on a sheet of paper in which there is a box for each of the eight digits in a given list. Have people write a digit in each box at the position they remember it being in. They can put an “X” in a box if they cannot remember the digit at a given position. In the *control* group, people should start recalling when you finish reading a list of eight digits. In the *suffix* group, at the end of each list give the digit 0. Tell those people that when they hear the 0 this is their cue to start remembering.

After you have given all 11 lists, then collect the response sheets and look at what people wrote down. Throw out the first list as practice. Then, count up the number of errors people made. What you should find is that memory for the lists will be worse in the suffix group than in the control group (see Zechmeister & Nyberg, 1982).

Stop and Review

Retrieval from short-term memory is affected by how much information is in memory, similar to what would be expected with a serial exhaustive search. That said, there are other possibilities, such as a parallel search with limited resources. Short-term memory retrieval is also affected by the order in which items were encountered. People often show serial position curves, with a primacy effect (better memory for things early on) and a recency effect (better memory for the most recent items). This latter finding can be disrupted with a suffix.

MEMORY FOR SERIAL ORDER

Short-term memory retains not only information content but also the **serial order** items were encountered in. If someone gave you a telephone number, remembering just the digits is not sufficient. You need to know the proper sequence as well. For the most part, people are fairly good at remembering serial orders after they first hear it (provided the amount of information is within normal short-term memory capacity). When people do forget the serial order, they do not do so randomly but in systematic ways. For example, there is a serial position effect, with elements at the beginning and end of an order remembered in their correct location better than items in the middle. Also, if things are remembered out of order, they are likely to be close to one another. For example, if you mess up the telephone number 123–4567 you are more likely to misremember it as 123–5467 than as 163–4527. Using an organization adopted by Henson (1998) we look at three classes of theories of memory for serial order in short-term memory.[2]

Chaining Models

In **chaining models** (Ebbinghaus, 1885/1964; Lewandowsky & Murdock, 1989) it is assumed that in short-term memory there is a series of associative links. Order information is recovered by moving along the chain. A problem with this view is that if people cannot remember an item the chain should be broken and they should not be able to continue. However, some approximation of the lost item could be used to pick up items further along the chain, perhaps with more remote associations with items not immediately following a given item. Typically, forgetting results in only a partial loss of information.

Ordinal Models

In **ordinal models**, serial order is captured by information about where a given item occurs along a dimension relative to the others. For example, in the **perturbation model** (Estes, 1972) information in short-term memory is organized as a hierarchy of chunks. Every item is regulated by a control unit that manages the chunk. These control units themselves may be grouped together by higher-order control units. One such a hierarchy is given in Figure 4.15. The item-to-control unit associations convey order information. This accounts for the fact that misorderings are more likely to occur at a local level and within chunks than across them. For example, a phone number such as 123–4567 is divided into two chunks: 123 and 4567. It is more likely that a person will misorder 4 and 5, because they are in the same chunk, than 3 and 4, because they are in different chunks.

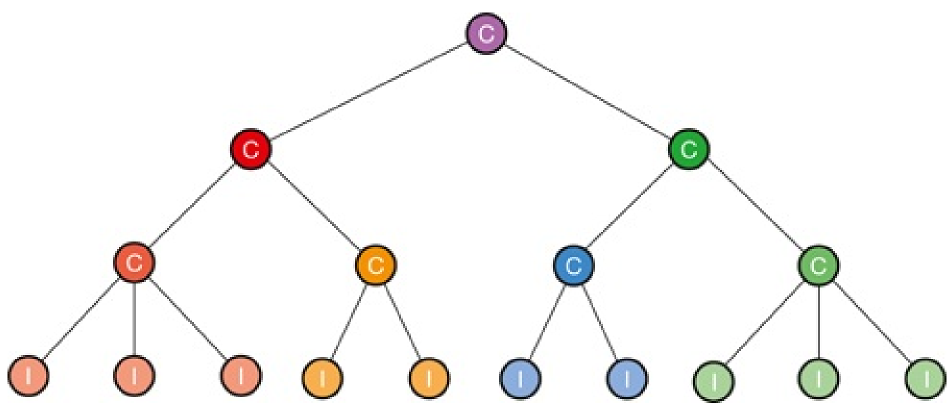

FIGURE 4.15 *A Hierarchy of Control Units as Theorized by the Perturbation Model*

Adapted from: Estes, W. K. (1972). An associative basis for coding and organization in memory. In A. W. Melton & E. Martin (Eds.), *Coding Processes in Human Memory* (pp. 161–190). New York: Wiley

Another ordinal model is the **inhibition model** (Burgess & Hitch, 1992), which suggests that inhibition, a mechanism of attention, is used to recover serial order. The idea is that as a person proceeds through a list the retrieval process selects the most active or accessible item, which is usually the first in the series. As each item is retrieved and reported, the system then inhibits it and sends activation to the next item in the order, which is now the most active. Inhibition keeps that previous item from being recalled again. Serial order information falls out of this process.

The inhibition of recently processed short-term memory information is seen in the phenomenon of **repetition blindness** (Kanwisher, 1987). Repetition blindness is observed in studies in which people read sentences presented in a rapid serial visual pre sentation (or RSVP) format. Essentially, words are shown one at a time in the same location on a computer screen in a relatively rapid fashion but still slowly enough that people can read them. If the same word is repeated within a short time span, people claim to not have seen the second occurrence of it. For example, for the sen tence “When she spilled the ink, there was ink all over” people are likely to not report the second “ink,” even though this makes the sentence ungrammatical. This is because “ink” had been recently processed and inhibited in short-term memory. As a result, people have trouble processing it again, even though they are looking right at it.

Positional Models

For **positional models**, serial order is conveyed by associating each item with its position in a sequence. The simplest versions are **slot-based models** (Conrad, 1965), which assume that short-term memory is a series of ordered slots (or boxes) and that information is dropped into each one as it is encountered. To convey order, one simply reads off what is in the slots. Here, item and order information are stored together because each item is put in a slot in a predetermined order. However, there is little evidence to support such a simple view.

More sophisticated versions include **context-based models** (Burgess & Hitch, 1992), which exploit the fact that context is constantly in flux, even if at a subtle level. This includes both what is going on in the environment, as well as a person’s internal context of their physiological, emotional, and cognitive states. This shifting context is not random but varies in regular ways, as with neural oscillators, which can then be used to identify positions in a series. It is also well known, as you will see in Chapter 7, that context information is stored in memory. This context can be used to determine serial order information by reconstructing the order from the way that context is changing. In this view, misorderings occur because the contexts were similar. Items that are close in time are likely to have similar contexts than items farther apart. This can explain why local misorderings are more common than distant ones.

Finally, positional models can take into account salient positions in a series, such as the first and last positions, which are distinctive in the sequence (Henson, 1998). People can use these positions, and others defined in terms of them, to help reproduce a serial order. An advantage of such theories is that they can account for the fact that people sometimes make errors in which an item from a previous series is misremembered in the current one. Such an error is called a **protrusion**. When protrusions occur, the incorrect item is remembered in the same position as it was in the prior series. This suggests that position information, in some way, is stored with the items in short-term memory.

Neurological Support

The fact that there are different theories of serial order memory suggests that the way we figure out how to put things in the proper sequence is a complex process that may involve different types of information used in different ways. Marshuetz (2005) showed that a number of brain regions are involved, each playing a different role. The explicit need to remember order information requires the hippocampus, perhaps because the order itself becomes a source of content to be learned. Also, serial order memory involves increased activity in the prefrontal and parietal regions. The dorsolateral prefrontal cortex (BAs 9 and 46) is involved in the allocation of the attention needed to encode and extract a sequence of items. Also, the part of the parietal cortex used to code numerical magnitude (e.g., knowing that eight is larger than four) is also involved.

There is also evidence that the premotor cortex (BA 6) is involved in chunking items into a sequence and in the timing of that sequence. Moreover, the motor cortex (BA 4) is involved in more detailed aspects of serial order. This makes sense from an embodied cognition perspective. Serial order is critical for many motor behaviors that would be impossible without doing things in the proper order (e.g., walking, eating, or tying your shoe laces).

Stop and Review

Retrieval from short-term memory can involve retrieving the items' serial order as well. Serial order memory is a complex process that is influenced by the associations formed between items, how the elements are chunked, and knowledge of where in a series a given item was encountered. Chaining models emphasize the associative links among items. Ordinal models assume that serial order is captured in relative order information. Finally, positional models assume that spots in a series are directly represented in short-term memory. These ideas about serial order information are supported by findings that different types of serial order information are associated with different neurological processes or regions.

PUTTING IT ALL TOGETHER

Dealing with information in a more immediate manner involves sensory and short-term memories. The recurrent issues for these memory systems are how much information a system can hold, and for how long, and how it is lost. In terms of the capacity, for the sensory registers, regardless of whether you are talking about iconic memory, echoic memory, haptic memory, or whatever, capacity is very large, essentially whatever can be processed by the sensory receptors. In comparison, the bottleneck of the system is short-term memory, which can hold a small number of items, either seven or four, depending on how you count. This limit can be increased by structuring or chunking the knowledge into something more meaningful. This allows the individual pieces to hang together. If you have synesthesia, this can help with this process. In addition to knowledge about content (what is remembered), short-term memory also keeps track of the sequence in which things were encountered. This is done by linking items into a chain, chunking knowledge into a hierarchical structure (like your social security number), suppressing recently encountered items, or exploiting regular changes in context.

How long can these memory systems hold on to information? For the sensory registers, these are very brief periods of time, anywhere from a quarter of a second to four seconds, depending on the modality. So, not very long at all. This allows you to continually bring in and process new sensory information from the world. Short as it is, it is long enough for us to build up a picture of the world. As suggested by work in anorthoscopic perception and trans-saccadic memory, this is done in an object-based manner. For short-term memory, if you continue to attend to things they can stay in short-term memory for a very long time. However, when your attention moves away they only hang around for 30 seconds or so. Early items in a set may be transferred to long-term memory but later items are less likely to have that happen to them.

Again, an important issue in memory for many people is not remembering, but forgetting. For the sensory registers, forgetting happens with the passage of time. The more time that has passed, the less there is. For short-term memory, while there may be a small amount of memory loss through some kind of decay process, the bulk of the forgetting is due to interference from other items. The absence of immediate inference is what produces the recency effect, which itself can be disrupted by any subsequent inference that serves as a suffix effect. If it is remembered, this information is likely to be retrieved in a way consistent with either a serial exhaustive or parallel, limited capacity manner.

STUDY QUESTIONS

1. What is the point of having sensory registers as memory systems?
2. What are the basic principles of iconic memory and why does it have these characteristics? Echoic memory? Haptic sensory memory?
3. What does anorthoscopic perception tell us about sensory memory?
4. What are some of the basic characteristics of trans-saccadic memory?
5. What does the existence of change blindness say about the nature of visual short-term memory?
6. What is the capacity and duration of short-term memory? How can this be extended?
7. How can the presence of synesthesia influence a person's short-term memory for information?
8. How does forgetting typically occur in short-term memory?
9. How is information retrieved from short-term memory?
10. How easy or difficult is it to distinguish between serial and parallel processes in human memory?
11. What is the serial position curve, and what does it have to do with short-term memory?
12. How is short-term memory able to keep track of the order in which things occur? What are the three basic classes of theories of short-term serial order memory?

KEY TERMS

- anorthoscopic perception
- cascading processes
- chaining models
- chunking
- context-based models
- decay
- echo
- echoic memory
- fixation
- haptic sensory memory
- icon
- iconic memory
- inhibition models

- interference
- object files
- ordinal models
- parallel process
- parallel search
- perturbation model
- positional models
- primacy effect
- protrusion
- recency effect
- repetition blindness
- saccade
- sensory registers
- serial exhaustive search
- serial order
- serial position curve
- serial process
- serial self-terminating search
- short-term memory
- slot-based models
- suffix effect
- synesthesia
- trans-saccadic memory

EXPLORE MORE

Here are some additional readings that you can explore to get better insight into sensory and short-term memory.

Brown, G. D. A. (1997). Formal models of memory for serial order: A review. In M. A. Conway (Ed.), *Cognitive Models of Memory* (pp. 47–78). Cambridge, MA: MIT Press.

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NOTES

1 See Cowan (2015) for a historical perspective on this paper and the handling of ideas that are out of step with current lines of scientific thinking.

2 See Acheson and McDonald (2009), as well as Perham, Marsh, and Jones (2009), for the idea that serial order memory is supported by language processes.

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CHAPTER 5

Working Memory

The previous chapter dealt with the retention of information in the short term. We saw that short-term memory includes conscious experience. However, conscious experience involves more than just retaining information over time. Things we are conscious of, or at least near conscious awareness of, are being thought about. This "thinking" implies an active processing or manipulating of information. For example, when you are thinking about how to get to a mall that you have never been to before, you combine various bits of knowledge that you already have: the layout of the city, information from a map, knowledge of traffic patterns in that area, and conversations with your friends about the location of the mall. By actively using this information, you can determine the best route to take. This involves the controlled use of information in short-term memory. Because of the special nature of this kind of processing, this is referred to as **working memory**. The phrase *short-term memory* is reserved more for the brief retention of information. In fact, some researchers have considered working memory and short-term memory to be different psychological constructs (e.g., Cantor, Engle, & Hamilton, 1991).

This chapter overviews some of the major issues involved with working memory. We begin with one of the more popular theories of working memory, Baddeley's multicomponent model. We examine the role of each part of working memory from this perspective and some of the memory phenomena associated with it. Regardless of how working memory is best conceived, these sections highlight a number of things that working memory does well and poorly. After the exposition of the multi-component model, we consider other views of what working memory is and how it operates, including Cowan's embedded processes model and Engle's controlled attention theory. Finally, some applications of working memory to more complex levels of processing are considered.

BADDELEY'S MULTICOMPONENT THEORY

Among memory researchers, the best-known theory of working memory is **Baddeley's multicomponent model** (Baddeley, 1986, 2000; Baddeley & Hitch, 1974). For this theory, working memory is made up of several components: (1) the phonological loop, (2) the visuospatial sketchpad, (3) the episodic buffer, and (4) the central executive. An overview of the model is shown in Figure 5.1. The phonological loop, visuospatial sketchpad, and episodic buffer are specialized subsystems under the control of a generalized **executive controller**, which runs the operation. The **phonological loop** is the part of working memory responsible for processing verbal and auditory information. The **visuospatial sketchpad** is responsible for processing visual and spatial knowledge. The **episodic buffer** is where multimodal information from different sources is combined or bound together. Note that there are some bits in gray in Figure 5.1 that are not formal parts of the model but that are likely to be involved at some level.

The phonological loop and visuospatial sketchpad are relatively separate from each other. This is based on how different types of information tend not to influence one another. For example, if you are trying to think about verbal information, such as reading a chapter in a book, you are more likely to experience interference and distraction if you are exposed to other verbal or auditory information, such as listening to music. However, your reading is relatively unaffected by spatial tasks, such as tapping out a beat with your hand. Conversely, visual-spatial tasks, such as tracing a route on a map, are disrupted by other visual-spatial tasks but not by verbal tasks (Baddeley & Andrade, 2000; Fougnie, Zughni, Godwin, & Marois, 2015; but see Vergauwe, Barrouillet, & Camos, 2010). There is interference if two tasks use resources from the same part of working memory. For example, people have difficulty detecting visual and auditory signals if they are maintaining visual and auditory images, respectively (Segal & Fusella, 1970, 1971) or, conversely, evaluating mental images when viewing distracting pictures (Lloyd-Jones & Vernon, 2003). Cross-system deficits are typically observed only when executive controller processes are affected, such as when the tasks involve relatively large memory loads (Morey & Cowan, 2005).

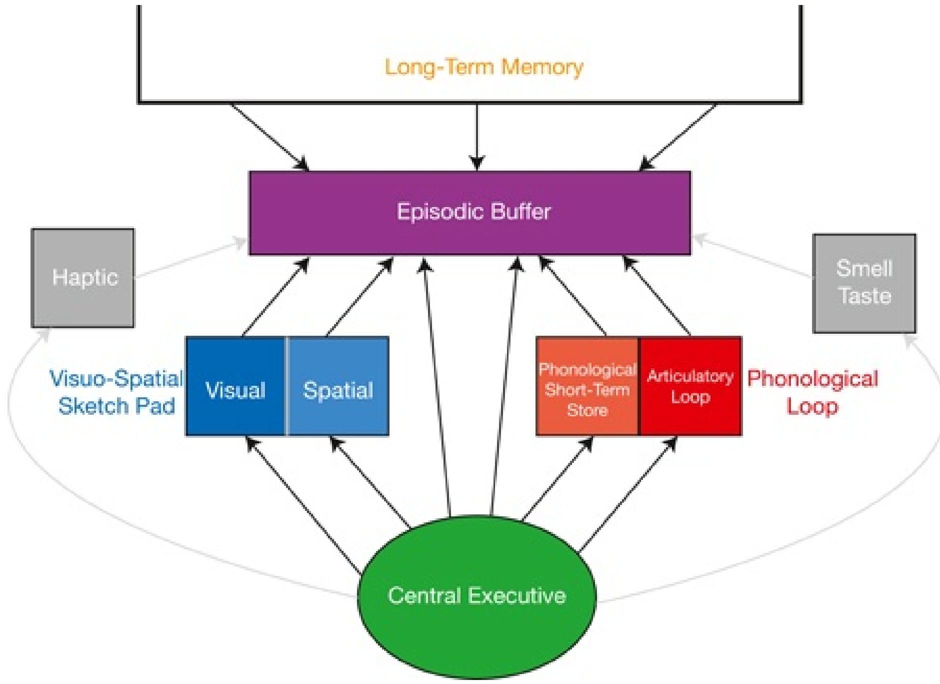

FIGURE 5.1 *Baddeley Model of Working Memory*

Adapted and expanded on from: Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Science*, *4*, 417–423

The episodic buffer helps *bind* information from different sources. Like the phonological loop and visuospatial sketchpad, the episodic buffer is a limited capacity, temporary storage system. However, it brings together information from other portions of working memory as well as long-term memory. The result of this binding is a unified episodic memory of an event or experience that can then be stored in long-term memory. So, for example, your memory for an event will include how things looked, the sound of a person's voice, where things were, what they meant, and so on, all integrated into a single memory trace such as an event model.

The central executive is the control center of Baddeley's model. Although each subsystem has some capacity, the central executive has additional capacity that it can devote to a subsystem if the demands on it become taxing. For example, if you are thinking about a difficult problem while walking, you may stop walking because the visual-spatial part of working memory that helps you navigate has some of its resources taken away by the central executive to be used elsewhere. An important job of the central executive is to regulate the flow of information in the current stream of thought as a sort of supervisory attentional system (Norman & Shallice, 1986).

Phonological Loop

Of the various working memory components, the phonological loop has received the most attention. This may be because much of the work on working memory follows from research in the verbal learning tradition, and the phonological loop is concerned with processing verbal items. Studies of the phonological loop focus on linguistic materials, which are either read or heard, although other acoustic items have been used. As such, the parts of the brain often implicated in phonological loop processing include the more linguistic aspects of the temporal lobe (Jonides, Lacy, & Nee, 2005).

The phonological loop has two parts: the **phonological store** and the **articulatory loop** (see Figure 5.2). The phonological store is a temporary storehouse, whereas the articulatory loop is for active rehearsal. A helpful analogy is that the phonological store is like an inner ear, which listens to what we say to ourselves, and the articulatory loop is like our inner voice, which says what we are thinking. The way the system works is that information first enters the phonological store. Over time, this information decays and is eventually lost. To prevent this, the articulatory loop actively rehearses the information in the phonological store, refreshing and preserving it. The more information that is held in the phonological store, the harder the task of the articulatory loop, and the more likely it is that information will degrade to the point that it cannot be recovered and, so, is forgotten. Please note that, while we are talking about a phonological loop here, this same basic process is thought to operate for language processing in general, including non-spoken languages such as American Sign Language (Wilson & Fox, 2007).

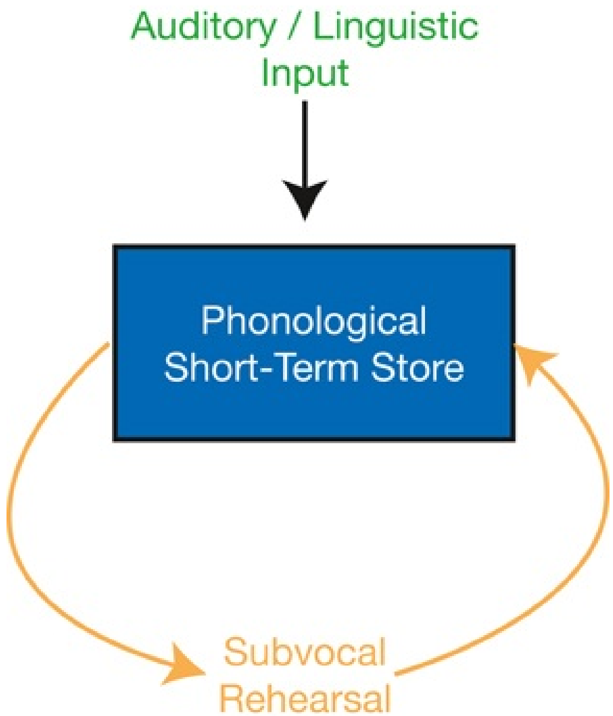

FIGURE 5.2 *The Phonological Loop, with the Phonological Store and the Articulatory Loop*

Adapted from: Gathercole, S. E. (1997). Models of verbal short-term memory. In M. A. Conway (Ed.), *Cognitive Models of Memory*, pp. 13–45. Cambridge, MA: MIT Press

To illustrate the role of the phonological loop, let's look at some major effects that have been observed (Gathercole, 1997). These provide insight into various characteristics of working memory. Along with the description of each of these is an explanation of why they occur.

The **word length effect** is the finding that a person's word span is smaller for longer words than for shorter words. This can be broken down into two types of word length effects. The first is the *syllabic word length effect*, which is the finding that it is harder to remember words with more syllables than words with fewer syllables (Baddeley, Thomson, & Buchanan, 1975). This occurs because more time is needed to rehearse some items in a set, causing other items not to be refreshed, making them more likely to be forgotten (Cowan, Baddeley, Elliott, & Norris, 2003).

One finding related to the syllabic word length effect is that Chinese speakers have larger digit spans than English speakers, who in turn have larger digit spans than Welsh speakers (Hoosain & Salili, 1988). This is related to the digit word lengths for those languages. In Chinese the digits are all monosyllables, whereas in English some digit names are multisyllabic, thereby lengthening articulation time. For example “seven” in English, is “qi” in Chinese. Welsh is even worse than English. It has also been shown that the digit spans of Chinese–English bilinguals vary depending on which language people are speaking. Thus, it is not that Chinese speakers are necessarily smarter but it is the case that they are fortunate enough to have a language with syllabically simpler words for digits.[1] A similar line of reasoning, in terms of “articulation time,” explains the finding that memory spans are smaller with American Sign Language (ASL) than spoken language (Wilson & Emmorey, 2006). The signs take longer to produce.

The second word length effect is the *articulatory word length effect* which is the idea that processing can be affected by articulation duration, apart from the number of syllables. In other words, the longer it takes to physically say the words, the fewer that can be recalled. Keeping the number of syllables constant, more short-duration words, such as “wicket” and “bishop,” can be recalled relative to long-duration words, such as “harpoon” and “Friday.” While there is substantial evidence for the syllabic word length effect, the syllabic word length effect may not be replicable (e.g., Hulme et al., 2004; Bireta, Neath, & Surprenant, 2006).

The **articulatory suppression effect** is a reduced verbal span when people are speaking while simultaneously trying to remember a set of items (Murray, 1967; Peterson & Johnson, 1971). For example, suppose people are given a set of words to hold in the phonological loop. While they get the words, they say aloud some word over and over—for example, “the” (i.e., “the,” “the,” “the,” etc.). This results in memory span being reduced. In other words, talking about one thing makes it very difficult to remember something else. A more everyday example is if someone tells you his or her name and college major at a party while you are talking with someone else, this impedes your ability to rehearse and remember that person’s name and major. In some sense, this is the suffix effect run amok. What happens is that an articulatory suppression task, such as repeating the word “the,” takes up resources from the articulatory loop. As a result, information in the phonological store cannot be adequately refreshed and so it is lost from working memory.

The **irrelevant speech effect** is the finding that the phonological loop is less efficient when there is irrelevant speech in the background, even if it is in a language people don’t understand (Colle & Welsh, 1976). You may have had the experience of trying to read in a room where other people are talking. It is difficult to concentrate on your reading. This is because this additional information (the background voices) enters working memory and takes up some of the resources of the phonological loop, causing other information (what you are reading) to be harder to process and more likely to be forgotten.

This has implications for students (such as yourself) about the best way to study. Salame and Baddeley (1989) had students try to learn information either in silence or while listening to either instrumental music or music with vocals. The results are shown in Figure 5.3. As you can see, memory was best when students were in quiet conditions. However, when there was background noise that involved language, such as music with vocals, memory was worse. Listening to instrumental music had a moderate effect. The linguistic nature of the irrelevant speech of the music with vocals interfered with the operation of the phonological loop. So, when you study, it is best to do so under quiet conditions, if you can. If you must have background noise, choose instrumental music rather than music with vocals or, even worse, television.

PHOTO 5.1 *Because working memory processes similar information together, trying to do one task, such as reading a newspaper (which contains language), while another person is talking on a cell phone (which also contains language) can disrupt performance (in this case, this is an illustration of the irrelevant speech effect)*

Source: Ingram Publishing/Thinkstock

The **phonological similarity effect** is the finding that phonologically similar items are more likely to lead to errors (Baddeley, 1966; Conrad & Hull, 1964). That is, when the words share the same sounds (e.g., "whole," "bowl," "boat," "bone," and "phone") people forget more and make more errors than when the words do not share the same sounds (e.g., "whole," "line," "milk," "fire," and “hunt”). Performance is not as bad when the words in the list rhyme (share the same ending sound), worse when they are alliterative (share the same beginning sound), and worst when both of these are occurring throughout the list (Gupta, Lipinski, & Aktunc, 2005). In these circumstances, people are likely to misremember a similar sounding word. For example, if one of the words was “bowl,” people might misremember it as “roll,” which sounds similar but looks different, but not “fowl,” which looks similar but sounds different. As an everyday example, if you are busily working in the kitchen with someone and ask “Can you please pass me the bowl?” because their working memory is largely occupied by whatever it is that they are doing, they may pass you a roll instead of a bowl. In general, this phonological similarity effect occurs because information is degrading in the phonological store. When it is time for an item to be rehearsed, some reconstruction may be needed. Because phonological information is auditory, this reconstruction is based on the fragmentary phonological information that is available. When there are phonologically similar items, it is harder to keep track of which ones have and have not been rehearsed. This makes it more likely that an unrehearsed item is not refreshed and forgetting occurs (Li, Schweickert, & Gandour, 2000).

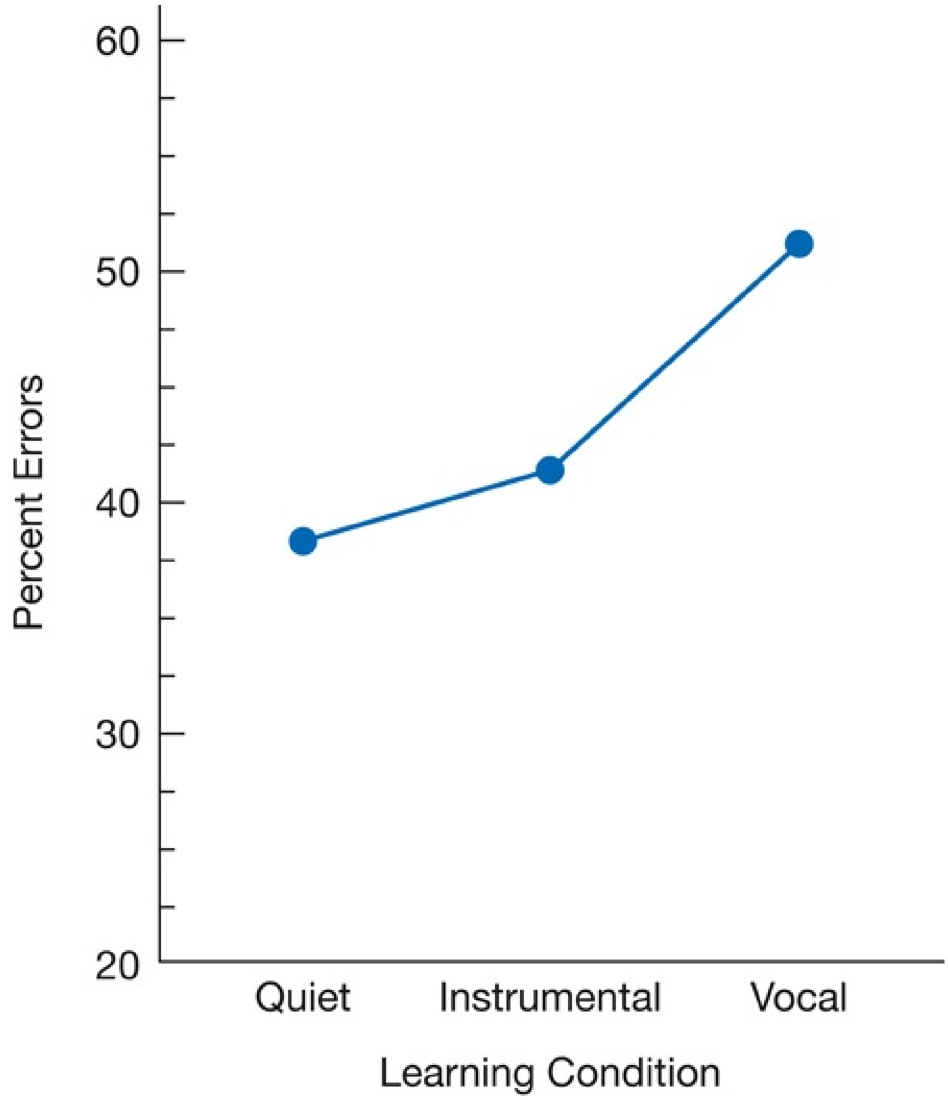

FIGURE 5.3 *Working Memory Performance With Different Types of Background Music*

Adapted from: Salame, P., & Baddeley, A. (1989). Effects of background music on phonological short-term memory. *Quarterly Journal of Experimental Psychology*, *41* A, 107–122

It should be noted that all of these effects do not take into account knowledge in long-term memory, which may be used to support what is happening in working memory. However, working memory is influenced by prior knowledge. For example, memory spans are larger for lists of words than for lists of nonwords. This is the **lexicality effect** (Hulme, Maughan, & Brown, 1991). People use long-term knowledge to support and reconstruct information in the phonological store. Information in long-term memory can even reverse some phonological loop effects. For example, for the phonological similarity effect, performance is worse when items are phonologically similar. However, if these words are embedded in the context of meaningful sentences, this effect reverses: performance is better for words that are phonologically similar rather than different (Copeland & Radvansky, 2001; see also MacNamara, Moore, & Conway, 2011). This commonly occurs with poetry and song lyrics. People can draw on knowledge of the sentence along with memory of the rhyme scheme to come up with the appropriate response. For example, you could remember "pole" if you know that all of the words in a set rhyme with "hole" and the sentence was something like "The vaulter was surprised when he discovered that he had somehow broken his ____." Thus, people can use long-term knowledge to aid short-term recall.

TRY IT OUT

In this chapter, the most straightforward way to assess working memory is to look at aspects of the phonological loop which rely on verbal materials. In this section we'll look at two ways to manipulate phonological loop processing, namely, the word length effect and articulatory suppression. Ideally you should have at least 24 participants for each of these tasks. Now, using these basic ground rules, here are some things you could do:

Word length effect. For this task, create two lists of eight words (nouns). One list of words should all be one syllable long. The other list should all be three or four syllables long. For each person, pick out five of the words from one of the lists at random. Read them to each person at the rate of one word per second. At the end of the list, have the person write down the words in the order that they heard them. After a person is done recalling the first list, read the second list and have the person recall that one. Across your participants, have half of the people get the short words list first and the other half of the people get the long words list first. Score performance on the two lists separately by counting up the number of words correctly recalled for each of them. If all goes well, most people should have better recall for the list of short words than for the list of long words (see Neath, 1998).

Articulatory suppression. For this task, create 10 similar lists of five two-syllable words each. For each person, read a list of words to the person at the rate of one per second. For five of the lists have people simply listen and then write down the words in the order that they heard them. For the other five lists have the people say the word "the" over and over from the time you start reading to the time they finish recalling the words. What you should find is that people remember fewer words when they were articulating than when they were not.

Stop and Review

Baddeley's multicomponent model is the dominant theory of working memory. It is made up of a phonological loop, a visuospatial sketchpad, an episodic buffer, and a central executive. The phonological loop is geared toward processing verbal and acoustic information. This is done using the phonological store, which is more passive, and the articulatory loop, which is more active. Evidence for the operation of the phonological loop comes from the word length effect, articulatory sup pression, the irrelevant speech effect, the phonological similarity effect, and the lexicality effect. These effects are embodied in a sense that the phonological loop is treating the information as if it were spoken or heard, even when it is only visually read.

Visuospatial Sketchpad

Another working memory subsystem is the visuospatial sketchpad, which is responsible for visual information, such as size or color, and spatial information, such as the relative orientation of entities, or spatially manipulating an object in one's own head. Although some researchers suggest that there are separate spatial and visual components (Darling, Della Sala, & Logie, 2009; Klauer & Zhao, 2004), we treat them together here. As you read about different aspects of the visuospatial sketchpad, note how they involve some element of embodied cognition, as if working memory is simulating the world and how a person would interact with it.

Also, note that the visuospatial sketchpad involves more processing from the right hemisphere than the left. This is consistent with the idea that the right hemisphere is dominant for spatial and holistic processing. Also, the premotor cortex (BA 6) is important for the visuospatial sketchpad's active processing (Smith, 2000), as well as portions of the parietal lobes involved in perception (Jonides et al., 2005).

One of the main tasks of the visuospatial sketchpad is the construction, maintenance, and manipulation of **mental images** that are isomorphically related to perceptual images. The more working memory capacity a person has, the more accurate working memory is for visual characteristics, such as color (Allen, Beilock, & Shevell, 2011). For example, mental images are sensitive to object size and viewer distance. People are better able to identify the components of an image if it is large or the viewing distance is close (Kosslyn, 1975).

Mental images must be actively maintained or rehearsed in the visuospatial sketchpad or they degrade. This is outlined in the CRT model of visual imagery (Kosslyn, 1975). When you watch television, the image you see on a screen (which used to be a cathode ray tube, or CRT) is not projected all at once. Instead, it is continuously refreshed, with the image constantly scanning from top to bottom and then starting over again. The speed at which this is done is the refresh rate. Thus, even a static image is constantly decaying and being reconstructed. The CRT model of visual imagery assumes that a similar process occurs in the visuospatial sketchpad. A mental image is constantly decaying and being refreshed. This is also similar to the operation of the articulatory loop as described earlier.

In support of this, like the word length effect, people find it harder to maintain complex rather than simple mental images (Kosslyn, 1975). The more components there are to the image, the more elements the visuospatial sketchpad that need to be refreshed and the more opportunity there is for forgetting.

How does the visuospatial sketchpad manipulate information, and toward what aim? One of its roles is as a surrogate for physical reality. A person might make decisions about objects at two different locations by **mental scanning** across their mental image. Mental scanning time increases with the distance that needs to be covered. In one study, Kosslyn and his colleagues had people memorize a map of an island, like the one in Figure 5.4. The task was to verify some aspect of one of the island locations. The results, shown in Figure 5.5, reveal that response time increased with the distance from one location to another. Mental imagery processes in working memory rely on similar visual and spatial processes as those used during perception, except that people produce the images themselves rather than having them present in the environment (Kosslyn, Ball, & Reiser, 1978; Kosslyn & Pomerantz, 1977).

Processing information in the visuospatial sketchpad has isomorphic perceptual qualities similar to what it would be like in reality. A striking example of this is a study by Intons-Peterson and Roskos-Ewoldsen (1989) with students at Indiana University Bloomington. In this study, students did a mental scanning task, much like in the Kosslyn study. However, rather than using a map of a fictitious island, the students used their knowledge of the Bloomington campus. More importantly, the students were asked to imagine themselves going from one location to another, carrying either a balloon or a load of bricks. In both cases, response time increased with greater distances. Moreover, the increase in response time was greater when the students imagined they were carrying the heavy load rather than the light one. Thus, the operation of working memory can capture aspects of the world in a direct fashion.

FIGURE 5.4 *Map of an Island Used in Kosslyn's Mental Scanning Experiments*

Adapted from: Kosslyn, S. M., Ball, T. M., & Reiser, B. J. (1978). Visual images preserve metric spatial information: Evidence from studies of image scanning. *Journal of Experimental Psychology: Human Perception and Performance*, *4*(1), 47–60

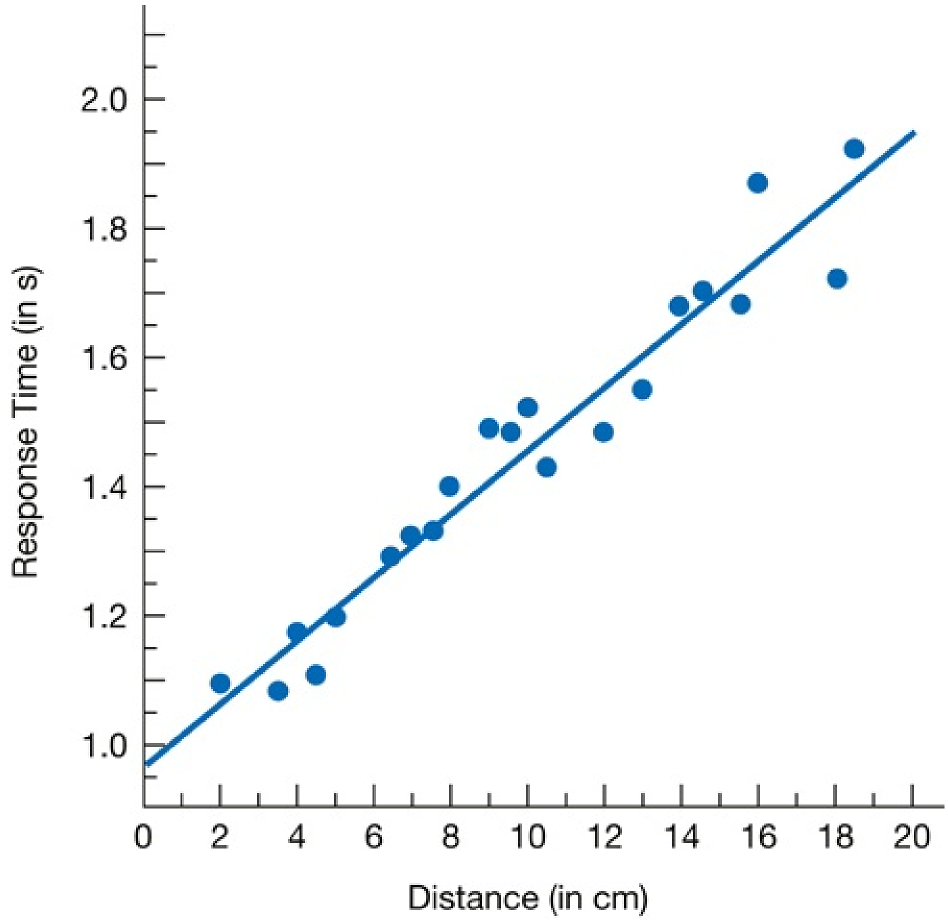

FIGURE 5.5 *Response Time in Kosslyn's Mental Scanning Study as a Function of Distance on the Island Map*

Adapted from: Kosslyn, S. M., Ball, T. M., & Reiser, B. J. (1978). Visual images preserve metric spatial information: Evidence from studies of image scanning. *Journal of Experimental Psychology: Human Perception and Performance*, *4*(1), 47–60

Another visuospatial working memory process is **mental rotation**, in which people need to mentally turn an object. This might be done so that people can make a decision, such as identifying it. Imagine that a sign that is upside down. You must mentally rotate the letters or numbers to decipher the message. Another possibility is that people may need to compare two objects for some purpose, such as working on a jigsaw puzzle. You mentally rotate the pieces to see if they fit together before actually picking them up and trying them out.

Research has shown that, like visual scanning, mental rotation has characteristics that mimic physical rotation. The greater the degree of rotation required, the longer it takes to do the task. In a study by Shepard and Metzler (1971), students saw pairs of three-dimensional figures, like those in Figure 5.6. Participants had to say whether the figures were the same or different. These figures could be rotated either in the picture plane (as with the pair on the top) or be rotated in depth (as with the pair in the middle). The results, as seen in Figure 5.7, showed that response time increased with the degree of rotation that was needed.

Mental rotation reflects embodied cognition. People mentally rotate as if they were actually turning an object (Gardony, Taylor, & Brunyé, 2013). This is reinforced by the finding that if there is unseen tactile feedback, such as feeling the actual object being turned in one's hand, then performance improves. This benefit is not observed if people simply feel the object and it is not rotated, if a different object is rotated in their hand, or if the rotation is in a different direction (Wraga, Creem, & Proffitt, 2000; Wraga, Swaby, & Flynn, 2008). Finally, mental rotation is easier if the object is easier to rotate in real life (Flusberg & Boroditsky, 2011), again, even though all that is actually being rotated is a thought (and they don't weigh anything).

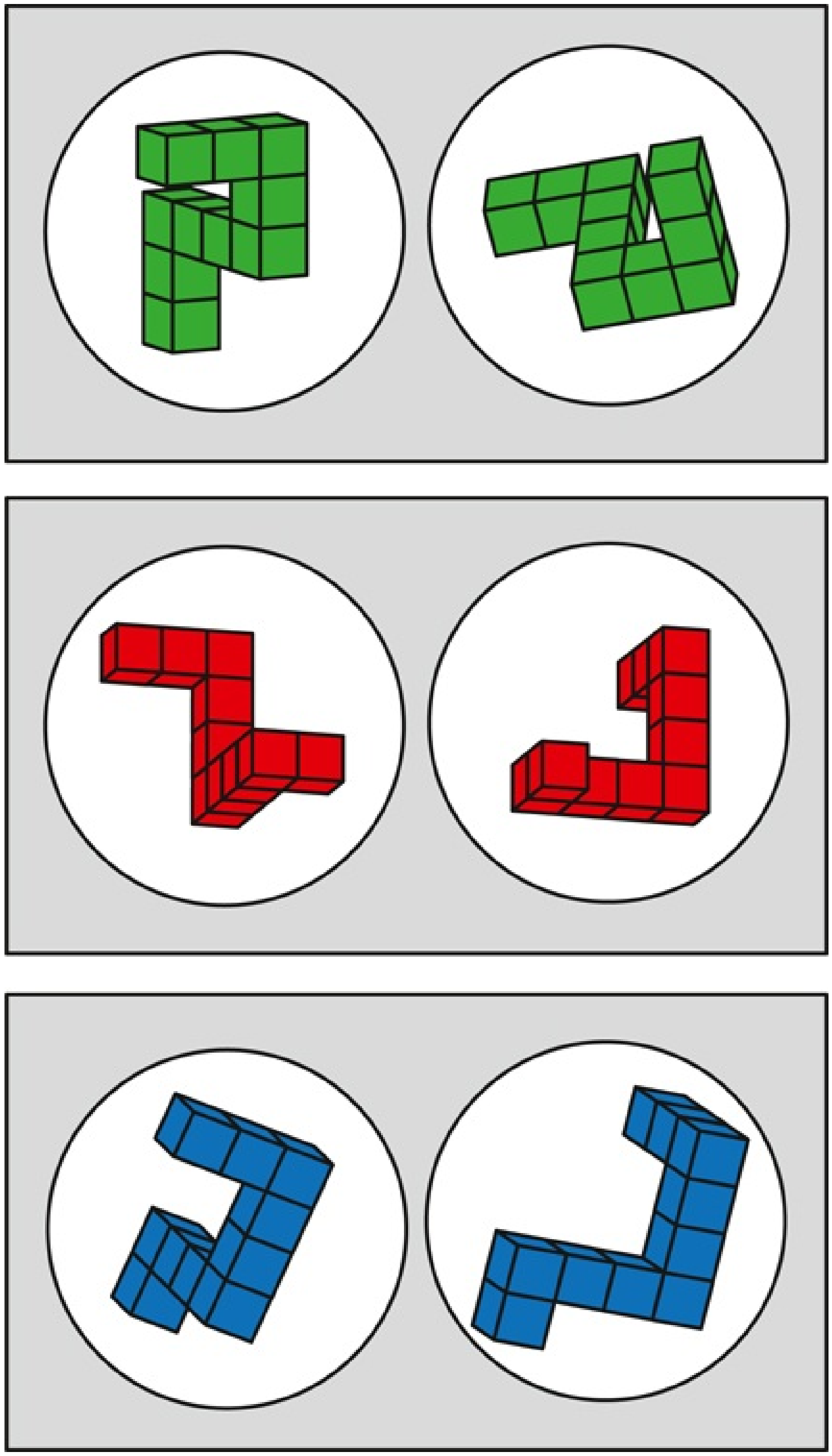

FIGURE 5.6 *Object Pairs Used in Shepard and Metzler's Mental Rotation Study*

Source: Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, *171*, 701–703

In terms of the neurological underpinnings of mental rotation, the parietal lobes tend to be more involved, along with some coordinating support from the frontal lobes. Furthermore, if the mental rotation is particularly demanding, there may be more involvement of the left hemisphere than the right, suggesting an increase in analytic processing (Just, Carpenter, Maguire, Diwadkar, & McManis, 2001). It is difficult to clearly identify one type of processing with any one brain structure. Many visuospatial processes involve more right-hemisphere activity when more holistic processing is needed. However, when more analytical processing is needed, there can be more left hemisphere dominance.

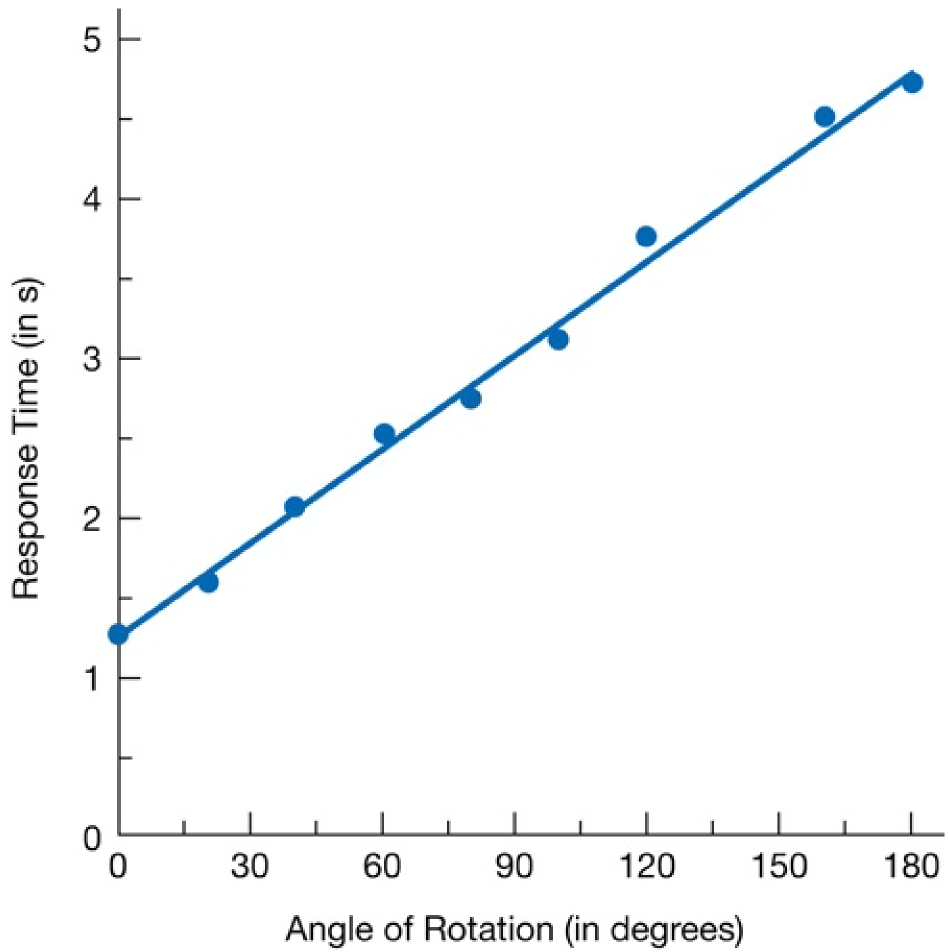

FIGURE 5.7 *Response Time Results from Shepard and Metzler's Mental Rotation Study*

Source: Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, *171*, 701–703

The operation of the visuospatial sketchpad is also observed in the phenomenon of **boundary extension** (Intraub & Richardson, 1989; for a review, see Hubbard, Hutchison, & Courtney, 2010), which is memory for details beyond what is seen is boundary extension (Intraub, Bender, & Mangels, 1992). As noted in the discussion of iconic memory in Chapter 4, when we view the world we are only getting bits and pieces of it at a time. What gives us the experience of being in a world filled with more visual information than is actually available to us in the moment? In part, we fill in beyond the edges with what we *think* should be there. This is especially striking in memory of pictures, television shows, or movies. When you remember a movie, it is unlikely that your memory typically contains the experience of the edge of the screen and the theater beyond that. You remember more of the scene than you actually saw.

In studies of boundary extension, people might see a series of photos, such as those in Figure 5.8. Then, they would be given probe pictures with the task of indicating whether each was seen before (old) or not (new). Some of these would be old, original versions of the pictures. Some shots would be closer up and others would be photos taken from further back (thereby extending the boundary of the original). It was found that people made more errors by selecting more pictures that were taken from further out. Moreover, if people draw what they saw, their drawings tend to include information beyond the boundaries of the image. People fill in the surrounding space using the visuospatial sketchpad and then incorporated this extension into their memory of the scene. Boundary extension occurs even when images were viewed as briefly as 42 ms (Intraub & Dickinson, 2008).

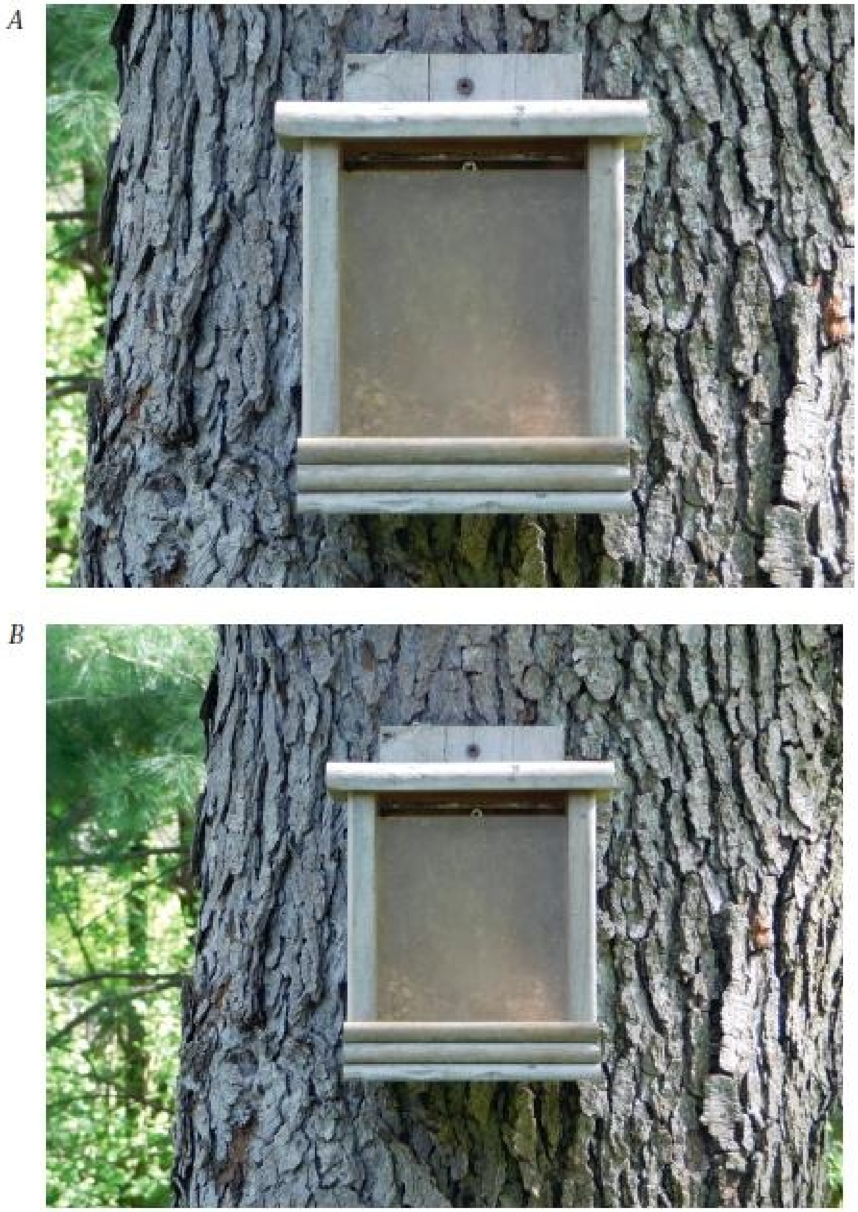

FIGURE 5.8 *Example of Pictures as They Would Appear for a Study on Boundary Extension: If People Saw Picture A, There Was a Bias to Later Say That Picture B Was Actually Seen Because the Boundaries of Picture A Were Expanded*

Source: Cassidy Crane

Still, boundary extension is not an automatic process. For it to occur, a person must think that what is being viewed is a scene from the world. There must be some sort of background, even if it is only imagined. Pictures of objects without a background do not produce boundary extension (Gottesman & Intraub, 2002; Intraub, Gottesman, & Bills, 1998). Thus, the operation of the visuospatial sketchpad depends on knowledge in long-term memory. If a picture does not activate this knowledge, then no boundary extension occurs.

There are other visuospatial sketchpad processes that involve the interpretation of real or perceived motion. Because of this, it is called **dynamic memory** (Hubbard, 2005).

When we watch moving objects and blink or look away briefly, they often continue in motion. This continued motion is captured in the visuospatial sketchpad. **Representational momentum** is a bias for people to misremember the location or orientation of an object further along its path of travel than it actually was the last time it was seen (Freyd, 1987; Freyd & Finke, 1984). It is as if people have difficulty stopping the object in their visuospatial sketchpad. An example of a representational momentum is shown in Figure 5.9. Here, a box appears to be rotating across a series of displays. After the last display there is a delay and people are given a test display. The task is to say whether the object is in the same orientation as it was when it was last seen. These test objects can be the actual last display, a box rotated slightly backward, or a box rotated slightly forward. The results, shown in Figure 5.10, reveal a tendency for people to misremember the box as being further along in its rotation than it actually was.

Other studies have shown representational momentum along the path of an object's trajectory (Hubbard, 1990). For example, if you see a car moving along a street, and then it disappears behind a bush, you would misremember it as being further along its path of travel than it actually was. Representational momentum is influenced by the speed of an object, with faster objects exhibiting more representational momentum (Hubbard & Bharucha, 1988). This effect takes into account regular properties of the world. For example, you may misremember a pendulum beginning its backswing when that has not yet occurred (Verfaillie & Y'dewalle, 1991) or remember a ball bouncing off a wall before it happens (Hubbard & Bharucha, 1988).

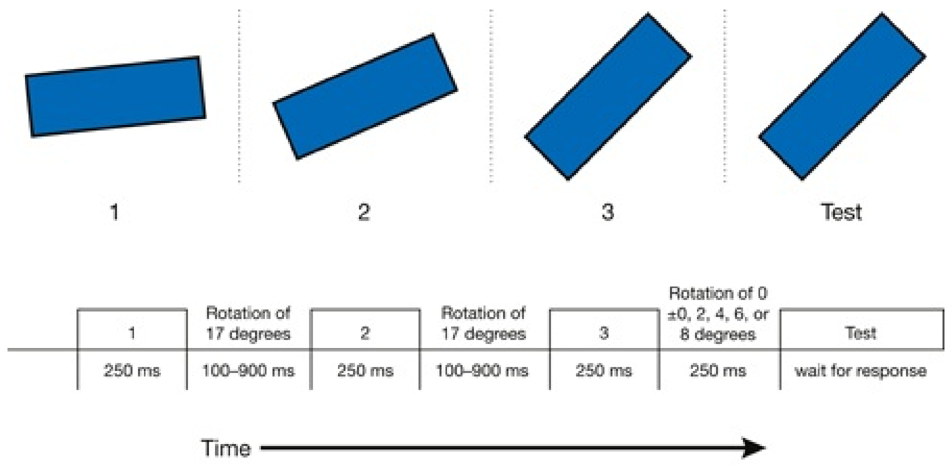

FIGURE 5.9 *A Representational Momentum Display*

Source: Freyd, J. J., & Finke, R. A. (1984). Representational momentum. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 10*, 126–132

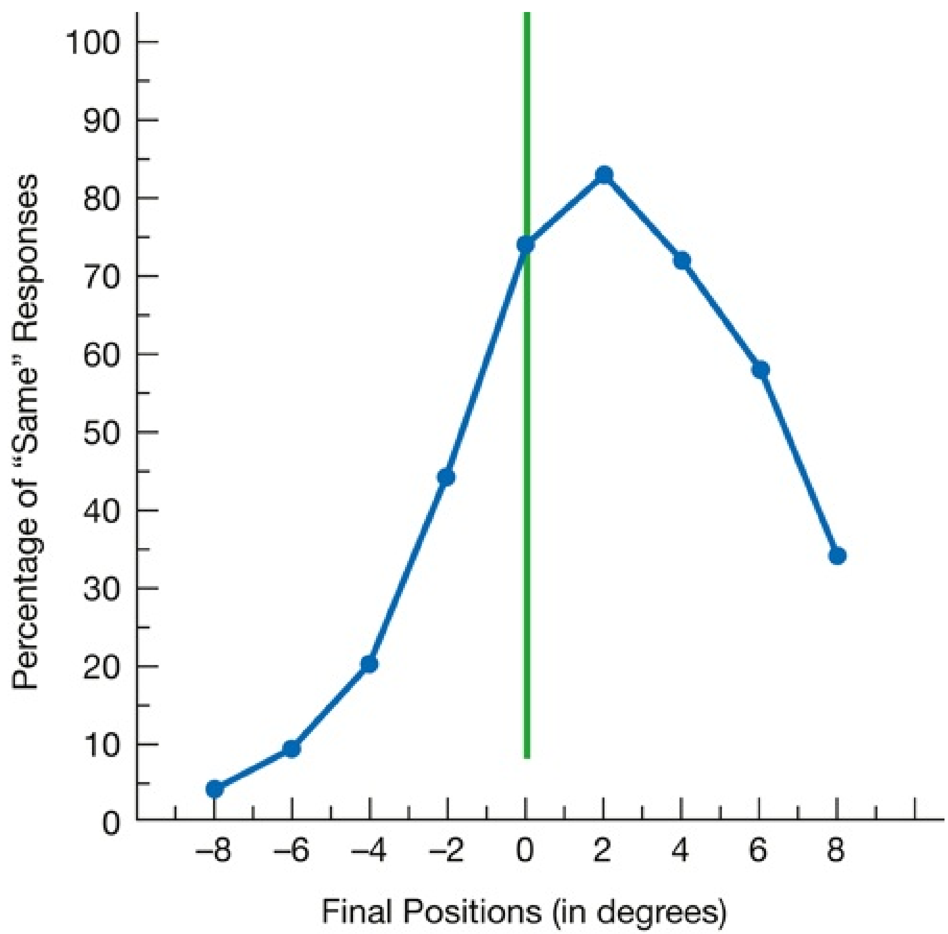

FIGURE 5.10 *Results from a Study of Representational Momentum (Note That Estimates of Final Position Are Distorted in the Direction of the Object's*

Motion)

Source: Freyd, J. J., & Finke, R. A. (1984). Representational momentum. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *10*, 126–132

Representational momentum also reflects properties such as a centripetal force (Hubbard, 1996). This involves active processing in the visuospatial sketchpad because the amount of distortion is directly related to the speed of the mental rotation. The faster people mentally rotate, the greater the distortion (Munger, Solberg, & Horrocks, 1999). It should be noted that representational momentum tends to follow medieval impetus theories of motion rather than Newtonian or other modern views. This is true even for physics experts (Kozhevnikov & Hegarty, 2001). Thus, this aspect of working memory has only a limited influenced from knowledge in declarative long-term memory (but see Courtney & Hubbard, 2008). It is important to note that representational momentum influences are not limited to visuospatial memory as they are also observed with music pitches moving up or down (Kelly & Freyd, 1987).

Representational gravity is the finding that memory for object positions tends to be distorted toward the earth, especially when the objects are not supported (Freyd, Pantzer, & Cheng, 1988; Hubbard, 1995). An example is shown in Figure 5.11. Here, people viewed a plant that was initially on top of a table or suspended by a hook. Then, in a later display, the table or hook was absent. People were then tested for their memory of the plant's location. People tend to remember it as being lower in the picture than it actually was, which is consistent with the idea that representational gravity is influencing the visuospatial memory, moving the plant lower. Note that, in this case, the image is not in motion. The motion is implied by an existing component of the world that interacts with the objects, namely gravity. In general, when static images convey likely interactions among objects, the visuospatial sketchpad infers some type of motion (Coventry, Christophel, Fehr, Valdés-Conroy, & Herrmann, 2013).

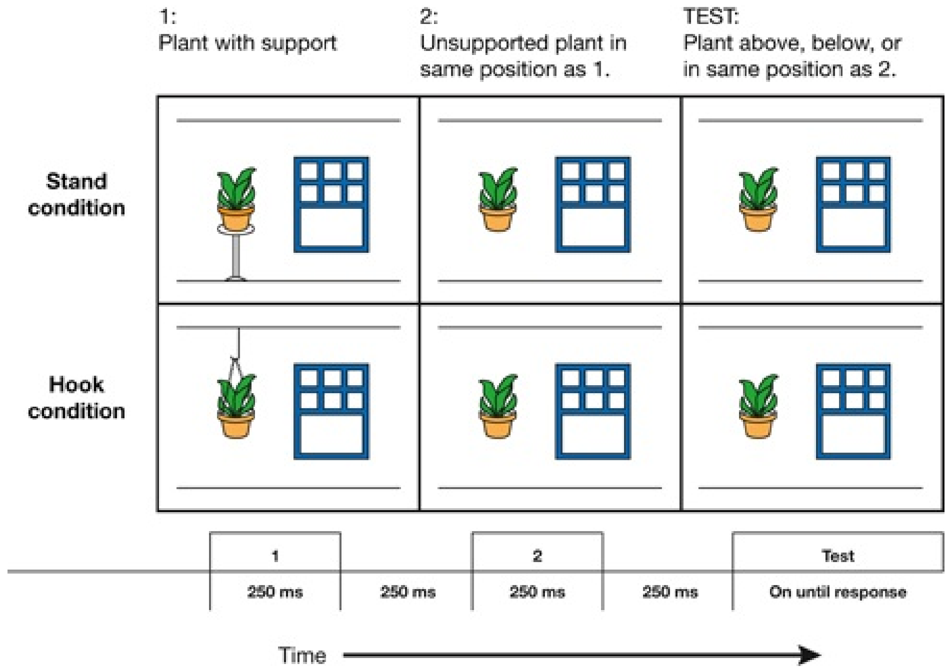

FIGURE 5.11 *Representational Gravity Display*

Source: Freyd, J. J., Pantzer, T. M., & Cheng, J. L. (1988). Representing statics as forces in equilibrium. *Journal of Experimental Psychology: General, 117*, 395–407

Similarly, if a circle is seen on an incline, it is remembered as being further down the incline, as if it had rolled. The greater the incline, the greater the distortion. Also, objects moving along a trajectory may be remembered as being lower than they originally were, as if being pulled down by gravity (Hubbard, 1990). Also, larger, and presumably heavier, objects fall faster than smaller ones do (Hubbard, 1997). Visuospatial working memory taking into account physical principles to anticipate what will happen next. If you see a paint can tipping off a ladder, you don't need to watch it fall to know that will be coming down and that you need to move out of the way.

Representational friction is the finding that moving objects slow down more when moving along another object (such as the ground) that can produce friction (Hubbard, 1995). The greater the implied contact with a surface or surfaces, the greater the implied friction. In some sense, representational friction puts the brakes on representational momentum. Overall, people are unconsciously predicting the outcome of events using the visuospatial sketchpad.

Stop and Review

The visuospatial sketchpad is dedicated to processing visual and spatial information. It captures many qualities of the world in an analog and isomorphic format. People treat the mental images as if they were seeing actual images. These images can degrade and be lost if they are not refreshed over time. The operation of the visuospatial sketchpad reflects the manipulation of mental images as if people were actually interacting with images and objects in the world. This is evidenced by mental scanning, mental rotation and boundary extension effects. The dynamic operation of the visuospatial sketchpad on information in working memory is seen in effects such as representational momentum, gravity, and friction to predict where things will be in the very near future.

Episodic Buffer

The **episodic buffer** is a recent addition to Baddeley's multicomponent model, and so there is less to say about it here. The role of the episodic buffer is to bind together information from various sources in working memory and long-term memory. This binding process uses the attentional processes and can be disrupted by concurrent tasks (Elsley & Parmentier, 2009). Episodic buffer integration was shown in a study by Jefferies, Lambon Ralph, and Baddeley (2004), in which people were given either lists of words or sentences with the task of recalling them later. While they were holding these items in working memory, people did a demanding distractor task that consumed central executive resources. What was found was that performance was disrupted on the sentence list task but not the word list task. This is because sentences require people to bind together the words into a coherent sentence. This is not needed in the word list task. With a heavier working memory load, people had difficulty doing this and so performance was hampered.

Another example of the operation of the episodic buffer is a study by Darling and Havelka (2010), in which people had to remember digits. These digits were presented one at a time either (1) at a single position on a screen, (2) on a number line, or (3) arranged in a keyboard pattern (such as that found on a telephone). They found that memory was better in the third condition because when the digits were shown in a keyboard layout people could bind spatial information together with the digit information to better remember the sequence.

Central Executive

The final component of Baddeley's working memory model is the **central**

executive. This is involved in the allocation of attention (i.e., deciding what to and what not to think about), as well as the active processing of information that is not handled by the subsystems. As such, the central executive is given the lion's share of what we consider "thinking." The central executive does most of the work of working memory. If researchers are interested in studying the central executive, they may tie it up by doing something else to see what impact its absence has. This can be done by giving a task such as generating a list of random numbers (which is much harder than it sounds). This causes people to do more poorly on tasks that require active thinking in which control over the flow of information is at a premium.

In some sense, the central executive serves to distribute memory resources. One thing that can improve performance is if there are more resources available. Activity that brings the body to a higher or optimal state of arousal has a positive effect on working memory performance. This is why you think more clearly when you've had enough sleep. Moreover, active executive processing is resource consuming and can show deficits when resources are low, such as when there are low levels of blood glucose and/or low levels of brain glycogen (Gailliot, 2008). Also, increasing physical activity increases your working memory performance. That said, after high levels of aerobic activity, such as running a marathon, explicit memory may be compromised, although implicit memory is largely unaffected (Eich & Metcalfe, 2009).

The disruption of the central executive is seen when there has been brain damage, particularly to the medial frontal lobes (BA 32), as revealed by EEG recordings (Gevins, Smith, McEvoy, & Yu, 1997). This can result in a symptom known as **dysexecutive syndrome**, where people lose some central executive functions that control their thought processes. With this syndrome, people may exhibit two types of behavior: perseveration and distraction. **Perseveration** is when people have been doing a task one way and need to do it another way but the switch is not made. For example, if people are first asked to sort a deck of cards by suit, they could do so easily. But if they were then asked to then sort the cards by value, they would continue to sort them by suit. There is a perseveration of the old mode of thinking and people cannot disengage from it to move on to the new way. What is especially odd is that people can report what the correct sorting strategy should be and may admit they are not following the new strategy even as they continue to follow the old one. Relatedly, some behaviors exhibit elements of distraction. **Distraction** occurs when people are supposed to be attending to one task but some elements of the environment take attention away from it. For example, if they are not currently processing information, attention might drift and become locked on some other stimulus in the environment.

Overall, the dysexecutive syndrome illustrates the attentional control that has been attributed to the central executive. When this component has been damaged, the flow of the stream of thought is disrupted, getting stuck on old processes and drifting out to unrelated areas.

Stop and Review

The episodic buffer is where information is integrated from the other working memory subsystems and long-term memory to make new integrated episodic memories. In comparison, the central executive coordinates what is attended to and what is not. People with brain damage can have problems with the central executive, pro ducing the dysexecutive syndrome. Dysexecutive syndrome can involve perseverations of no-longer-appropriate behaviors and distractions to irrelevant environ mental stimuli.

COWAN'S EMBEDDED PROCESSES MODEL

Another conception of working memory is **Cowan's** (1988) **embedded processes model** (see Figure 5.12). Here, working memory is not a separate part of memory, apart from long-term memory. Instead, working memory is a portion of long-term memory that is in a currently activated state. Working memory is, more simply, the part of a person's knowledge (as well as incoming information from the environment) that is in a more accessible or active state.

Within working memory is the focus of attention, which is those elements that attention is currently directed to. For this view, the focus of attention is about four items. Like Baddeley's model, there is a central executive, which directs where the focus of attention is to be within the set of memories to those that are in a currently activated state of working memory. Thus, overall, information in the focus of attention is what a person is currently attending to and thinking about at the moment and the larger portion of working memory is composed of information that is readily available to be brought into the focus of attention as needed.

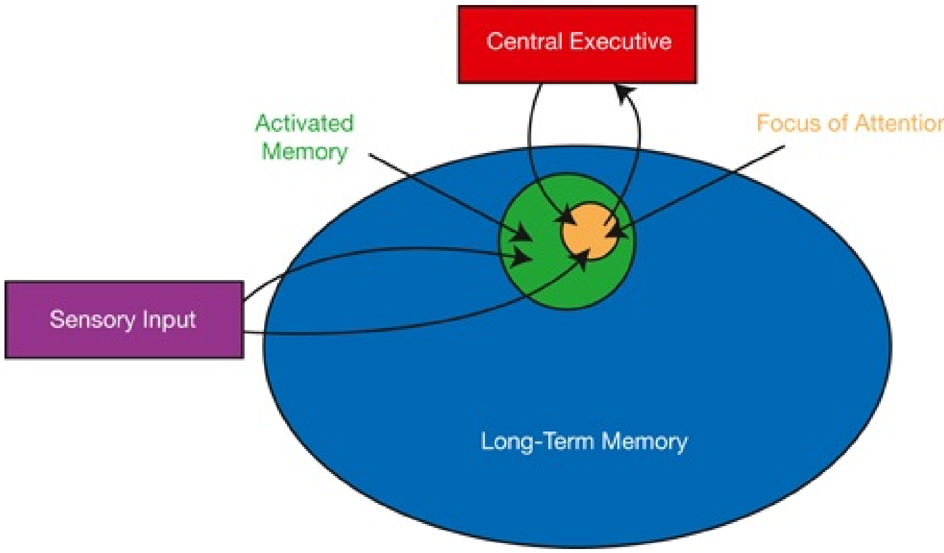

FIGURE 5.12 *Schematic of Cowan's Attentional Focus Theory of Working Memory*

Adapted from: Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information-processing system. *Psychological Bulletin*, *104*(2), 163–191

This conception of working memory is also related to the earlier idea of long-term working memory (Ericsson & Kintsch, 1995). **Long-term working memory** is a way for people to coordinate large amounts of information. Essentially, long-term working memory is a set of retrieval cues held in working memory that reference information in long-term memory. By using these cues, people can quickly access the information as needed.

In some ways, this approach to working memory makes a lot of sense. Early theories of memory and cognition were based on the computer metaphor, that is, the idea that the mind works in a way similar to a digital computer. Well, in a computer when information is actively processed, a copy of it is put into an active state, namely in the Random Access Memory (RAM) of the machine. Information enters RAM either through some an input device or from permanent storage, such as a hard drive. It is moved from one part of the machine to another (RAM), where it can be actively worked on (via the CPU). The bits in RAM are flexible and can accommodate any pattern of information. Well, the human brain just does not work this way. While there are different parts of the brain that process information in different ways, there is not a separate part of the brain that brings in information from other parts to be actively processed. There is no part of the brain that is a separate working memory store. Instead, the patterns of neural firing in the various parts of the brain are involved in representing the ideas are active when a person is thinking about them. This is more in line with Cowan's embedded processes model.

ENGLE'S CONTROLLED ATTENTION MODEL

Another working memory theory is **Engle's controlled attention model** (Kane & Engle, 2002). Like the embedded process model, there is no separate working memory store per se. Instead, this view assumes that working memory contents are the information that is currently in an activated state. What is important for this view is the idea the working memory performance is influenced by the effectiveness with which people can control the contexts and processes of memory and cognition via attention processes; that is how much cognitive control one has. There are two components to attentional control: (1) the scope of attention (how many things are captured by attention at a time), and (2) the control of attention (how effective is the control over where attention is directed) (Chow & Conway, 2015; Shipstead, Harrison, & Engle, 2015). This control of attention in working memory involves the frontal lobes, particularly the prefrontal cortex (Kane & Engle, 2002). Overall, for this view, measures of working memory span (see the next section) do not reflect how much control a person has in processing information in working memory.

This view can account for a broader range of findings, such as the fact that working memory can be disrupted by irrelevant tactile stimulation (i.e., feeling something crawling on your skin that you don't expect) (Dalton, Lavie, & Spence, 2009). For Baddeley's multicomponent model there should be a separate system for tactile information, and this should not disrupt processing much in other systems. In comparison, for Engle's view, the critical factor is how disruptive the processing is for the amount of attentional control it captures or requires.

Another major influence of working memory is long-term memory processing. For example, working memory capacity is related to long-term memory consolidation. People with larger working memory span scores show more from memory consolidation, especially during sleep (Fenn & Hambrick, 2015). Thus, people with greater working memory control at better at getting information into long-term memory.

Working memory ability is also related to the effectiveness with which people manage sources of interference and retrieve information from long-term memory. People with larger working memory capacities are better able to retrieve information than those with smaller capacities, and show smaller fan effects (see Chapter 8) (Bunting, Conway, & Heitz, 2004; Cantor & Engle, 1993; Radvansky & Copeland, 2006). Similarly, Kane and Engle (2000) found that people with larger working memory span scores showed less proactive interference. Put another way, people with smaller working memory capacities search through a larger set of information during memory retrieval, making their retrieval less efficient (Unsworth, 2007). As an illustration, imagine that you are trying to remember the name of a historical figure (say, Tycho Brahe). When you attempt this, other memories of other similar historical figures can produce interference (e.g., Galileo Galilei, Isaac Newton, Johannes Kepler, and Nicolaus Copernicus). Essentially, greater working memory control allows people to better select out which long-term memories are needed to accomplish a task, thereby reducing any effects of memory interference.

In addition, any activity in your environment can intrude on your long-term memory search, such as seeing a picture of Francis Bacon in the book you are reading when you are trying to remember facts about Tycho Brahe. If you have better control over working memory, then this retrieval task is easier compared to people whose memory search drifts more toward inappropriate memories and environmental stimuli. Overall, working memory performance is improved by removing visual distractions if you just close your eyes while thinking (Vredeveldt, Hitch, & Baddeley, 2011).

In addition to managing what information is attended to and actively processed, another important part of working memory is knowing what to *not* attend to, or even to actively inhibit or suppress to keep out of the current stream of processing. Suppression is an attention mechanism that memory can use to control what is being currently thought about. Suppression keeps irrelevant information out of working memory or removes information that has become irrelevant or inappropriate (Conway & Engle, 1994). Thus, the suppression of irrelevant information is an important determinate to effective working memory processing (Kane, Bleckley, Conway, & Engle, 2001). The operation of suppression is closely tied to the prefrontal cortex (Kane & Engle, 2000).

The idea that different aspects of working memory, in terms of the control of processing, is supported by neuroimaging findings. Using event-related synchronization (ERS) and event-related desynchronization (ERD) analyses of EEG data, it has been found that different aspects of working memory processing are observed in different wavebands. Gamma band synchronization reflects the maintenance of information, alpha band synchronization reflects the control of attention and inhibitory processes, and theta band activity reflects the sequencing of information (Roux & Uhlhaas, 2014).

STUDY IN DEPTH

The suppression of information in working memory can create situations where performance is actually worse for things that were just thought about. This is illustrated in a study by Johnson et al. (2013). An outline of their procedure is shown in Figure 5.13. First, they showed 29 students from Yale University and Ohio State University two words on a screen for 1.5 seconds. Then there was a blank screen for half a second followed by screen, shown for 1.5 seconds, of an arrow that pointed to the location of one of the two words. The task was to say what the word at that location was. Then, after a delay, people were shown a target word, which could be (1) the word just said (refreshed), (2) the other word from the display (unrefreshed), or (3) a new word (control). The task was to say that probe word as quickly as possible. There were 144 trials in this study, with 48 trials in each of these three conditions.

The primary data of interest is the response times for people to say the word at the end of each trial. Because spoken responses were used, the researchers had to throw out any trials where a person misspoke, stammered, spoke too quietly to trigger the device, or made nonspeech sounds (e.g., coughing). The response time data is shown in Figure 5.14. What was found was that people were slower to say the target word if they had just said it in response to the arrow cue than if it was the other word they had seen (people were slowest in saying a new word). This suggests that when working memory processes something and then moves on to the next task it actively inhibits or suppresses the memory for what was just processed. This may occur because the just-processed information is typically not needed for a new task, and people are more effective if the newly irrelevant information is removed from working memory.

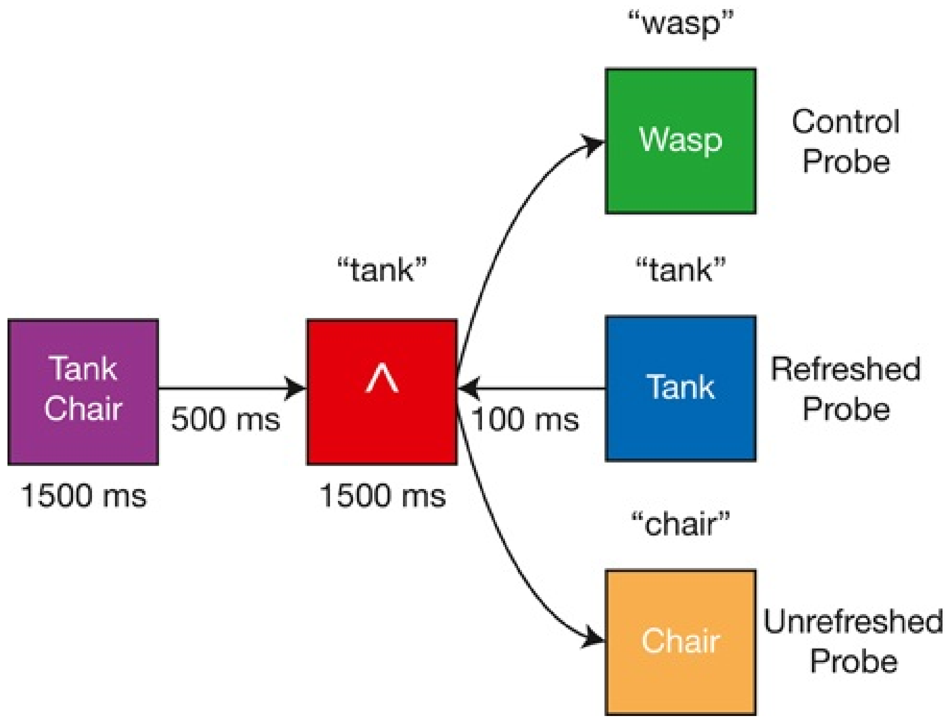

FIGURE 5.13 *Pattern of Vocal Response Times as a Function of Whether the Target Item Was Recently Refreshed or Not (Relative to an Unseen Control Condition)*

Adapted from: Johnson, M. R., Higgins, J. A., Norman, K. A., Sederberg, P. B., Smith, T. A., & Johnson, M. K. (2013). Foraging for thought an inhibition-of-returnlike effect resulting from directing attention within working memory. *Psychological Science*, *24*(7), 1104-1112

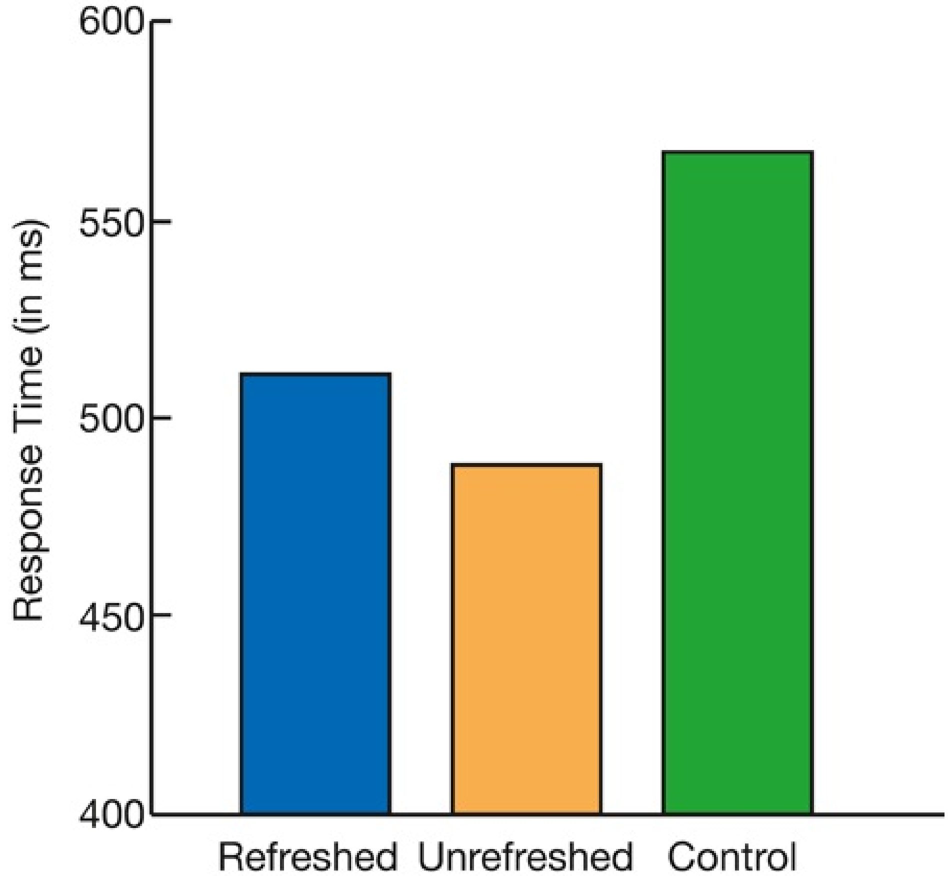

FIGURE 5.14 *Pattern of Response Times as a Function of Whether a Target Item Had Been Refreshed or Not*

Adapted from: Johnson, M. R., Higgins, J. A., Norman, K. A., Sederberg, P. B., Smith, T. A., & Johnson, M. K. (2013). Foraging for thought: An inhibition-of-returnlike effect resulting from directing attention within working memory. *Psychological Science*, *24*(7), 1104-1112

Stop and Review

Cowan's embedded processes model views working memory as not a separate store but as those contents of long-term memory that are currently active. Moreover, this information can vary in terms of whether it is part of the central focus of attention. Alternatively, Engle's controlled attention model suggests that working memory processing critically involves the controlled flow of the current stream of thought. This involves both the activation and maintenance of relevant information and the suppression of irrelevant information.

SPAN TESTS

In Chapter 4, we briefly examined measures of short-term memory span, including word span and digit span. These are **simple span** measures because they require people to do one simple task—remember something for a brief period of time and then report it back. However, this is a poor measure of working memory because the person isn't doing anything complicated. To address this, a number of **complex span** tests have been developed (see Conway et al., 2005, for their proper use). A complex span measure has at least two components. One is a retention component, such as the simple span measure, in which the person retains a set of information for a period of time. The other is an active processing component, depending on the working memory process of interest. Overall, this approach allows us to more closely measure working memory rather than short-term memory.

Complex span tests are important because they are highly related to measures of fluid intelligence (I.Q.) (Engle, Tuholski, Laughlin, & Conway, 1999; Unsworth & Engle, 2006; but see Mogle, Lovett, Stawski, & Sliwinski, 2008) and are separate from things like levels of expertise (Hambrick & Meinz, 2011). They are even related to things like decision-making, with people scoring lower on complex span tests being more likely to make impulsive decisions (Hinson, Jameson, & Whitney, 2003). Moreover, working memory processes may have a strong genetic component (Friedman et al., 2008).

Reading Span

One complex span test is Daneman and Carpenter's (1980) **reading span** test. In this test, people read aloud sets of two to six sentences, such as "The taxi turned up Michigan Avenue, where they had a clear view of the lake." At the end of each set, people must recall the last word in each of the sentences of that set. The largest set of words that can all be accurately recalled is the reading span score. The retention component here is remembering the final words. The processing component is thinking about the sentence to read it effectively. Sentence span is a good predictor of language processing (Daneman & Merikle, 1996). Language processing requires an active manipulation of knowledge, much like the processing component of the reading span task, which is absent in the simple span tests.

Comprehension Span

Another verbal span tests the **comprehension span** test (Waters & Caplan, 1996). For this test, people read sentences and then recall the last word of each one in a given set size from two to six. Rather than read the sentences aloud, people make sensibility judgments. Some of the sentences are sensible, such as "It was the gangsters that broke into the warehouse," whereas others are not, such as "It was the warehouse that broke into the gangsters." These sensibility judgments require deeper thinking about the meaning of the sentences, providing a better measure of higher-level working memory processes, such as those operating at the mental model level (see Chapter 7).

Operation Span

Another measure of working memory is the **operation span** test (Turner & Engle, 1989). In this test, people read aloud a two-step math problem, such as (2 × 4) + 1 = 8, and then indicate whether the solution is correct. After this, a word is presented. These math operation–word combinations are given in set sizes from two to six. At the end of each set, people recall as many words from that set as they can. The largest set size that can be accurately recalled is the operation span score. The retention component is remembering the words from each set, and the processing component is solving the math problems. The complex span test has been suggested to be a more domain-independent measure of working memory relative to reading span, which is more closely tied to language processing.

Spatial Span

One final complex span test discussed here is Shah and Miyake's (1996) **spatial span** test, which taps into spatial working memory. In this test, a series of letters are shown that have been rotated from the normal upright position. The initial task is to indicate whether the letters are normal or mirror reversed. This is the active processing component. Then, after a set of letters, people indicate where the tops of the letters were in the set by pointing to a predetermined set of locations. This is the retention component. Visuospatial working memory ability has consequences for visuospatial tasks. For example, Du et al. (2015) found that variations in visuospatial working memory span predicted the ability to successfully dock a spacecraft.

n-Back Test

Another popular assessment of working memory, particularly in neuroscience literature, is Kirchner's (1958) ***n*-back test**. In this task, people view a series of items, such as letters, digits, pictures, etc. For each item, people must indicate "yes" or "no" whether the current item is the same as the one *n* items back. Typically, *n* is two, but other values have been used instead. The idea is that people need to keep a certain number of items in working memory to do this task. The processing component is the judgment about the current item, and the retention component is the number of items held in working memory, although there is some suggestion that the *n*-back test may be more like a simple span than a complex span task (Redick & Lindsey, 2013). One characteristic of this test, unlike the other complex span tests, is that this is a continuously running task rather than being broken up into separate trials (for a meta-analysis and associated brain regions, see Owen, McMillan, Laird, & Bullmore, 2005).

Improving Your Memory

One point that should be apparent is that working memory is a very limited system. There are only so many things you can think about at once. As such, when you are learning something, you want to make some effort to allow working memory processes to focus on the information you are trying to process. Any distraction (other people talking, music playing, activity around you, etc.) will capture portions of working memory to process that other, irrelevant information. To improve your memory, you should try to study in places where such distractions are relatively minimized. A quiet library is a better place to study and learn than a crowded bus or a dorm room with videos and music playing.

Working memory can also be captured and drawn away by task-irrelevant thoughts that you may have. These could be things that you are concerned or worried about. When people are anxious, they think about whatever it is that is making them anxious. These task-irrelevant thoughts consume working memory resources, leaving less for whatever it is that they are supposed to be doing (e.g., studying, taking a test, or writing a paper) (Beilock, 2008). For example, people who are anxious about math do worse on math problems that they would otherwise be able to solve because their working memory capacity is consumed with irrelevant anxious thoughts (Ashcraft, 2002; Ashcraft & Krause, 2007). Negative and irrelevant information clogs up working memory.

Students who engage in expressive writing to disclose personal emotions can increase working memory span (Klein & Boals, 2001). This benefit is observed even weeks after the disclosure. Apparently, this expression decreases the implicit need or desire to think about the anxiety provoking thoughts, and so they intrude less. People who write about negative experiences showed a larger increase in working memory span than people who write about neutral or positive experiences. So, if you express thoughts about what is troubling you, it might help you increase your working memory capacity and improve your memory overall.

The Influence of Video Games

As you can see, there are a number of different measures to assess working memory. From these measures, one can estimate the working memory resources a given individual can bring to bear when they need to think. How fixed is this value? More importantly, can it be improved? Here we consider two lines of evidence suggesting that, to some degree, there can be improvements in working memory span.

The first of these is research on the influence of playing action video games (such as first-person shooter games) on processing in the visuospatial sketchpad. A number of studies suggest that people who spend time playing these video games improve some visuospatial working memory abilities (Feng, Spence, & Pratt, 2007), although more complex visuospatial abilities may not be affected (Blacker, Curby, Klobusicky, & Chein, 2014). This improvement is important, because any enhanced visuospatial ability could spill over to more complex tasks that place an emphasis on such these, such as science, technology, engineering, and math (STEM) fields (Sanchez, 2012; Uttal, Miller, & Newcombe, 2013). Moreover, people who are better at spatial tasks, which involve perspective taking, are also better at some social skills that involve taking another person's point of view (Shelton, Clements-Stevens, Lam, Pak, Murray, 2012). However, the broad-based influence of video games on memory is not clear and there is some suggestion that any influence of video games may only be minor at best (Unsworth et al., 2015).

PHOTO 5.2 *A ubiquitous activity in modern culture is playing video games; while there is some evidence that this activity may actually improve some aspects of working memory processing, the evidence is equivocal*

Source: James Woodson/DigitalVision/Thinkstock

Working Memory Training

The work with video games suggests that there might be some aspects of working memory that can be facilitated, at least to a limited degree, by some kind of training. A bigger question is whether working memory overall can be improved. This question is important because, as mentioned earlier, scores on working memory span tests are highly correlated with measures of intelligence. Is there some way to boost or improve working memory and thereby improve a person's level of intelligence? There have been a number of efforts to address this. Some studies have shown that, with weeks of training, there can be at least moderate improvements on both working memory span scores and measures of general intelligence (Au et al., 2015).

Other studies suggest otherwise. It is possible to improve performance on working memory span tests simply by having people practice taking them. It may be that the generalization of this improvement it either very limited (Waris, Soveri, & Laine, 2015) or that it does not generalize to other cognitive tasks at all, such as those reflecting general intelligence (Chooi, & Thompson, 2012; Harrison et al., 2013; Melby-Lervåg & Hulme, 2013; Redick et al., 2013;

Shipstead, Redick, & Engle, 2012). Moreover, many studies reporting an improvement may be underpowered (with not enough participants or observations) (Bogg & Lasecki, 2015) and so this limits the conclusions that can confidently be drawn. That said, more generally, some activities can boost cognitive performance. For example, playing a musical instrument can do this (Benz, Sellaro, Hommel, & Colzato, 2015; Gordon, Fehd, & McCandliss, 2015).

Although greater working memory capacity is often desirable, there are some circumstances when it is a disadvantage. In a study by Beilock and DeCaro (2007), students were given a series of math problems that required a complex solution at first. However, later problems could be solved more efficiently with a simple solution.[2] People with greater working memory spans were more likely to miss the simpler solution and continued using a more complex formula. However, people with lower working memory spans, because they preferred simpler solutions (as a result of their smaller capacity), were more likely to notice and use the simpler solution. In essence, people with more working memory capacity were better able to construct complex solutions, but they continued to use them even when a simpler solution was possible.

Stop and Review

There are a number of ways to quantify working memory capacity. Word and digit spans are simple span tests that only measure retention. Complex span tests have both retention and processing components. Complex span tests include the reading span, comprehension span, operation span, spatial span, and *n*-back tests. Performance on complex span tests is often related to performance on other measures, such as general intelligence. There has been some effort to explore whether training can improve working memory and, hence, intelligence. This includes playing action-based video games, and tasks that emphasize working memory training in general. While there is some suggestion that working memory can be improved, the reliability and generalizability of this evidence are uncertain.

PUTTING IT ALL TOGETHER

Memory is not just about holding onto information over time, it is also about doing something with that knowledge. This is working memory. Theories and ideas of working memory are still developing, with some disagreement about just what working memory is, how it relates to other types of memory, and what it does for us. So, just what is working memory? For Baddeley's multicomponent model there are different modules, each specialized for different types of information and processing. These include a phonological loop, a visuospatial sketchpad, an episodic buffer, and an executive controller. In comparison, Cowan's embedded processes and Engle's controlled attention models eschew the idea that working memory is a separate system. Instead, for these theories, it is much more unitary and akin to theories of attention.

How does working memory relate to other aspects of memory? For Baddeley's multicomponent model, working memory is a separate system from long-term memory. It interfaces with it using knowledge recovered from long-term memory and creates what will eventually be stored as long-term memories. The different systems of working memory correspond to different brain areas. Verbal/acoustic information is processed by different areas of the brain than visuospatial information is. The episodic buffer has a lot of processes ascribed to the hippocampus and the central executive has characteristics associated with frontal lobe attentional control. Alternatively, the other theories integrate concepts of working memory with general principles of memory and cognition, such as long-term memory structure and processes, and attention. For Cowan's embedded processes model, working memory is part of long-term memory. It is just that part that you are currently using. These are the neural assemblies that are currently firing, which is definitely limited in scope at any one time, or are primed to become involved in whatever you may be thinking about at the time. For Engle's controlled attention model, working memory is the control of the flow of thought, both for what is currently being thought about and for what is retrieved and stored in long-term memory. Working memory is thought about more as what you can do, and how efficiently you do it, than what you have.

What does working memory do for you? For Baddeley's multiple component model, working memory allows you to maintain different types of content, manipulate it, and put it together to form new ideas and understandings. It holds onto ideas as they are being thought about, with multiple thoughts being handled more or less simultaneous by different parts of working memory. For Cowan's embedded processes model, working memory is a spotlight focusing your attention on this or that idea. It is the active use of knowledge either from the past (long-term memory) or the present (sensory inputs). Finally, for Engle's controlled attention model, working memory is what makes you intelligent. The better you control the flow of your thoughts, the better you can think about things and the more intelligent you are.

STUDY QUESTIONS

1. What are the primary components of the Baddeley's working memory theory?
2. What are the primary components of the phonological loop?
3. What are some of the major findings that support the idea of a phonological loop?
4. What is the nature of the information in the visuospatial sketchpad?
5. What is the evidence that the visuospatial sketchpad captures real-world, physical processes?
6. What is the purpose of the episodic buffer?
7. What is the role of the central executive in working memory?
8. What are the major features of Cowan's embedded processes model? Compare and contrast this model of working memory with Baddeley's multicomponent model.
9. What are the major features of Engle's controlled attention model? Compare and contrast this model of working memory with other models of working memory.
10. What are the different types of span tests? What are the properties of each span test?
11. How effective are video games and working memory training tasks at improving memory and cognition?
12. What are some of the ways in which working memory capacity influences other types of thought?

KEY TERMS

- articulatory loop
- articulatory suppression
- Baddeley's multicomponent model
- boundary extension
- central executive
- complex span
- comprehension span
- Cowan's embedded processes model

- distractions
- dynamic memory
- dysexecutive syndrome
- Engle's controlled attention model
- episodic buffer
- executive controller
- irrelevant speech effect
- lexicality effect
- long-term working memory
- mental images
- mental rotation
- mental scanning
- n-back test
- operation span
- perseverations
- phonological loop
- phonological similarity effect
- phonological store
- reading span
- representational friction
- representational gravity
- representational momentum
- simple span
- spatial span
- visuospatial sketchpad
- word length effect
- working memory

EXPLORE MORE

Here are some additional readings for you to further explore issues of working memory.

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NOTES

1 For a comparison of English, Spanish, Hebrew, and Arabic, see Naveh-Benjamin and Ayres (1986).

2 Some of you may remember this as the Luchin's water jug problem.

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CHAPTER 6

Nondeclarative Memory

When we think about "remembering," we usually think about times when we are consciously aware of using our memories, such as trying to remember a person's name, the answer to an exam question, or where we left the car keys. This conscious, explicit use of memory is readily understood and apparent. We are also painfully aware of when this conscious memory has failed and we forget something. It is not difficult to talk about such experiences, the content of these memories, and our awareness of them. This is what makes them declarative memories. However, as prominent as this type of memory is, much of human memory operates at an unconscious level. Some of these unconscious memories are so far removed from awareness that it is very difficult, if not impossible, to accurately talk about them. These are **nondeclarative memories**. An interesting thing about nondeclarative memories is that they are relatively spared in cases of amnesia, which is consistent with the idea that this is a distinctly different way of remembering.

This chapter covers a number of aspects of nondeclarative memory. We start with some basic forms of learning and memory. One of these is classical conditioning, in which an organism learns to respond to signals that are predictive of future outcomes. In a sense, the organism is showing memory for previous environmental contingencies. We also examine more "cognitive" sorts of nondeclarative memory, particularly procedural memories and implicit memories. These are memories we use for various tasks that influence our behaviors without conscious awareness.

CLASSICAL CONDITIONING

Classical conditioning is one of the simplest forms of learning. Its formal discovery is credited to Ivan Pavlov (1849–1936), a famous Russian physiologist (see Chapter 1). As such, it is sometimes called **Pavlovian conditioning**. In classical conditioning, an organism learns that certain stimuli are reliable predictors of the imminent onset of other important stimuli (Pavlov, 1923). We examine classical conditioning in three forms: abstract; concrete, with the experimental situation used by Pavlov; and an example with human memory.

Learning Paradigm

The basic classical conditioning paradigm is shown in Figure 6.1. Classical conditioning starts out with a stimulus that elicits a response. This is the unconditioned stimulus, or US, and the response it elicits is the unconditioned response, or UR. Both are unconditioned because no learning is needed. It is a prewired stimulus– response relation. Another stimulus is introduced that initially elicits no response called a neutral stimulus, or NS. During learning, the NS is presented prior to the US in a reliable and consistent way. Over time, the organism associates the NS with the upcoming US. As a result, a preparatory response is made, as if the US were about to occur. The NS is now the conditioned stimulus, or CS, and the response that is made in the presence of the CS is the conditioned response, or CR.

As an example of classical conditioning, let's look at Pavlov's experiment. Pavlov received a Nobel Prize for his work on digestion. After getting his prize, he started researching the initial stage of digestion, salivation. Pavlov collected saliva from dogs by surgically inserting tubes into their mouths and feeding them. To his annoyance, Pavlov found that the dogs sometimes salivated when they weren't fed. Pavlov noticed that this salivation occurred with some regularity: it often preceded the actual presentation of food by when the dogs first saw the person who fed them. Pavlov suspected that the dogs had made a mental connection between the presence of the person who gave them the food and the food itself, so the dogs would salivate at the sight of the person. Pavlov decided to test his theory.

In his study Pavlov used meat as the US and the dogs' salivation as the UR. As an NS, he used a bell. He rang the bell before he gave the meat. Over time, the dogs learned that the bell meant food. The dogs began to salivate when the bell rang but before they were fed. The bell was now a CS and the salivation was a CR.

Another example of classical conditioning that relates more to human activity is the development of phobias. These are irrational fears people develop, such as a fear of elevators, open spaces, public speaking, and so on. These phobias can develop through a nondeclarative, classical conditioning process of which people are unaware. Specifically, people may have an initial experience with a situation that will come to elicit the phobia. For example, a person may have a negative public speaking experience; the anxiety experienced prior to public speaking is classically conditioned and the person begins to avoid that situation, creating the phobia.

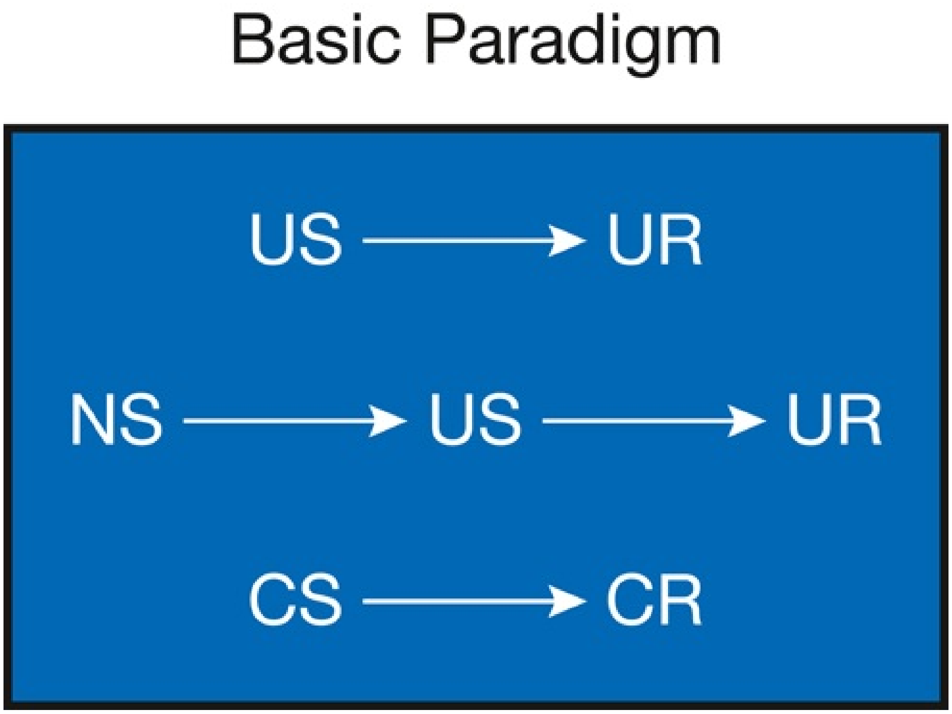

FIGURE 6.1 *The Basic Classical Conditioning Paradigm*

Happily, classical conditioning can also be used to get rid of phobias through a process known as **systematic desensitization** (Wolpe, 1958). In this clinical method, people are first asked to think of situations that are remote from the situation that elicits the phobia. Over time, people are slowly brought closer and closer to the situation that produces the phobia. At each step people remain at that stage until they do not feel disturbed. When a feeling of calm is associated with the situation at each stage, people then move on to the next stage. This continues until they finally reach the phobia-inducing situation, which is then classically conditioned to a relaxed feeling. At this point the phobia is conquered.

Associative Structure

What kind of association is learned in classical conditioning? There are two general possibilities, shown in Figure 6.2. The first is that the CS is directly associated with the CR. That is, the CS directly causes the CR to occur. This is a

stimulus–response association. The other is that the CS is directly associated with a memory of the US, which leads to the production of the CR. In other words, the CS is interpreted as predicting the onset of the US, so this elicits a CR in preparation for the US. This is a **stimulus–stimulus association**. While both possibilities can occur, in the vast majority of cases it is stimulus–stimulus associations that are learned. That is, the organism learns some predictive relationship.

Because of the prominence of stimulus–stimulus associations, what is important in classical conditioning is not contiguity but contingency. **Contiguity learning** is the idea that learning occurs when an NS and a US occur near each other in time. However, while timing is influential, it is not the critical factor. Instead, learning is driven by deriving some cause–effect relationship (however primitive). **Contingency learning** involves a sensitivity to the underlying causal structure rather than simply relying on things that happen to occur together in time.

Important Phenomenon

There are many important phenomena of classical conditioning. First, there is an acquisition period, or **learning curve**. The association is not effective immediately but takes a period of time to be learned. For example, it takes a while for a dog to learn that the sound of a bell is a signal for the presentation of food. This is because not all co-occurrences in the environment are meaningful but may be due to chance. By only encoding and using those relationships that are stable and meaningful, classical conditioning allows for a more direct way to prepare for events in the environment.

Of course, the environment is not always stable and one needs to adapt to change, not only by learning new associations but also by ceasing to respond to associations that are no longer relevant. When a CS is presented many times without a US, responding to that CS will cease. This type of forgetting is called **extinction**. For example, if a bell rings but no food is offered, the dog will no longer salivate when it hears the bell.

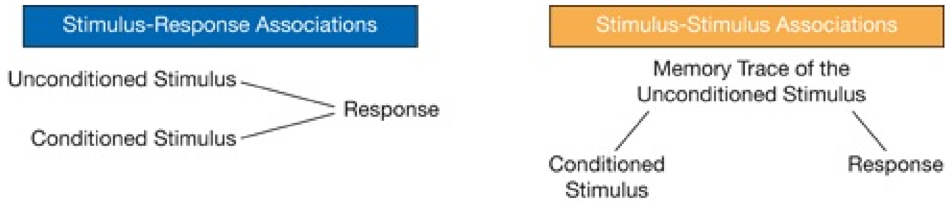

FIGURE 6.2 *The Difference Between Stimulus–Response and Stimulus–Stimulus Associations in Classical Conditioning*

When extinction has occurred, forgetting is not complete. This is revealed by two phenomena. The first is **spontaneous recovery**. This occurs when, after extinction, there is a long delay, and the CS is presented again. The CR, which was extinct, re-emerges but it is not as strong as before. The organism remembers the original association with the CS and forgets that it is no longer predictive and useful. This may be advantageous because environmental conditions might be present that make the CS meaningful again after an absence.

The other phenomenon related to extinction is **savings**. This is similar to the savings derived by Ebbinghaus (see Chapter 3). Savings shows that, after extinction, when relearning occurs, less time is required to learn than the first time. This suggests that some memory for that association remains, even though it appears to be forgotten.

The unconscious classical conditioning processes can influence our preferences. The **mere exposure effect** (Zajonc, 1968, 2001) is the finding that people prefer things they have been exposed to before. When we are exposed to something, we register it, even if only at a subconscious level. As long as there are no negative connotations associated with it, a mild positive association is established. That is, the absence of negative associations in nondeclarative memory is interpreted, at some level, as something we have experienced that does not hurt us. For example, if you eat a new berry that you've never seen before, and you do not get sick, then you will prefer that berry compared to another new one that you've never tried. Thus, we prefer things we have been exposed to before, even if we don't consciously remember them.

The effects of mere exposure influence our lives and our culture. As an example, Cutting (2003) showed that the development of the standard Western canon of French Impressionist paintings (the set of works identified by experts as the core or most important ones) is highly related to exposure. Adults' preferences were related to frequency of exposure in the culture rather than to whether people consciously recognized the painting, the complexity of the painting, or its prototypicality. Importantly, children who have not had this sort of exposure do not show this bias, so there does not seem to be anything special about the paintings at the core of the canon. What puts these paintings at the core is their frequency of exposure, which influences people's preferences. A finding related to this is preferences for songs that make up the top 40. People have been exposed to these songs more and so this is why they prefer them, even though there are other songs out there that they might like better. However, because they have not been frequently exposed to those other songs they show less of a preference for them.

PHOTO 6.1 *Advertisers try to get your attention in part to make their product name familiar and, consistent with the mere exposure effect, cause you to like it more*

Source: Michiaki Omori/amanaimagesRF/Thinkstock

This influence of memory on preferences is different from explicit memory for whether something is old or new. Different parts of the brain are activated in these situations, depending on the judgments people make. Specifically, the preference judgments that drive the mere exposure effect involve the right lateral frontal lobe, which is not observed with standard memory judgments (Elliot & Dolan, 1998).

The strength of the mere exposure effect is not constant and it can vary (Bornstein, 1989). It grows larger with more exposures, up to a point. With more exposures (e.g., over 100), the effect starts to decline. The effect is also more likely to occur when something is presented in multiple contexts rather than the same context over and over. Similarly, the mere exposure effect is greater with a delay between the time when the information was received and when the preference ratings are given. Finally, there is an embodied aspect to mere exposure. If people are chewing gum when they are exposed to stimuli, they show a mere exposure effect if the items are Chinese ideographs, but not if they are words (Topolinski & Strack, 2009). This is because the words could be spoken but the mental and neural machinery that would simulate this is taken up by the action of moving one's mouth to chew the gum.

INSTRUMENTAL CONDITIONING

The other major tradition in conditioning research is **instrumental conditioning**, such as when you learn putting your finger in a light socket is a bad idea. Unlike classical conditioning, where one is learning to prepare for an upcoming event, in instrumental conditioning one is acting on the environment and then remembering and evaluating the consequences of those actions. Much of instrumental conditioning can be captured by Thorndike's law of effect. This states that the consequences of an action that have a positive outcome will be reinforced, where-as consequences that have a negative or neutral outcome will not be reinforced. Reinforced means that the behavior is more likely to occur in the future. Essentially, with the law of effect, the energy that one has available can be directed toward activities that benefit one's self and away from activities that either provide no benefit or may actually cause harm.

The domain of instrumental conditioning is far too extensive to be adequately covered here. However, it should be noted that we have many nondeclarative memories that have been brought about through instrumental conditioning. Often, people are unaware that their behavior is being influenced by prior memories of both pleasant and unpleasant events. Instrumental conditioning is, in some cases, the use of unconscious memories to shape our behaviors and thoughts.

CAUSAL LEARNING

More recently, the work on conditioning has been extended to an understanding of human causal learning. That is, how does a person figure out the cause and effect relations in the world? For example, learning the causal relations that are needed to understand how technology works, what causes diseases, or how to find food. In essence, this is what goes on in conditioning. An organism learns which events predict other events (often some sort of causal relation) so that it can prepare for it. An example of two possible causal structures for the presence of a virus and two symptoms is shown in Figure 6.3 to give you an idea of what causal associations are. Many of the same principles that are observed in conditioning are also observed in causal learning (e.g., Mitchell, Lovibond, Minard & Lavis, 2006). Read the Study in Depth box on page 185 to get a better idea of the strong relationship between classical conditioning and studies of causal learning.

At this point, the extent to which the memory principles that underlie conditioning are also driving causal learning is unclear. There are a number of theories that try to explain this type of memory (Perales & Shanks, 2007). Some of these are based on theories of conditioning, such as associative models (Shanks & Dickinson, 1987) that involve the Rescorla–Wagner (1972) model of classical conditioning. In comparison, others are based on normative information about event probabilities, such as the Power PC theory (Cheng, 1997). Still others assume a more rule-based approach using the idea that people are drawing inferences (Mitchell, Lovibond, & Gan, 2005). It should be noted that causal learning is more effective when people have an opportunity to interact with a system, although it can occur through passive observation (Enkvist, Newell, Juslin, & Olsson, 2006). When engaged in causal learning, people often think about the assumed underlying mechanisms of the situation rather than thinking more probabilistically and abstractly (which would give a better understanding) (Park & Sloman, 2013).

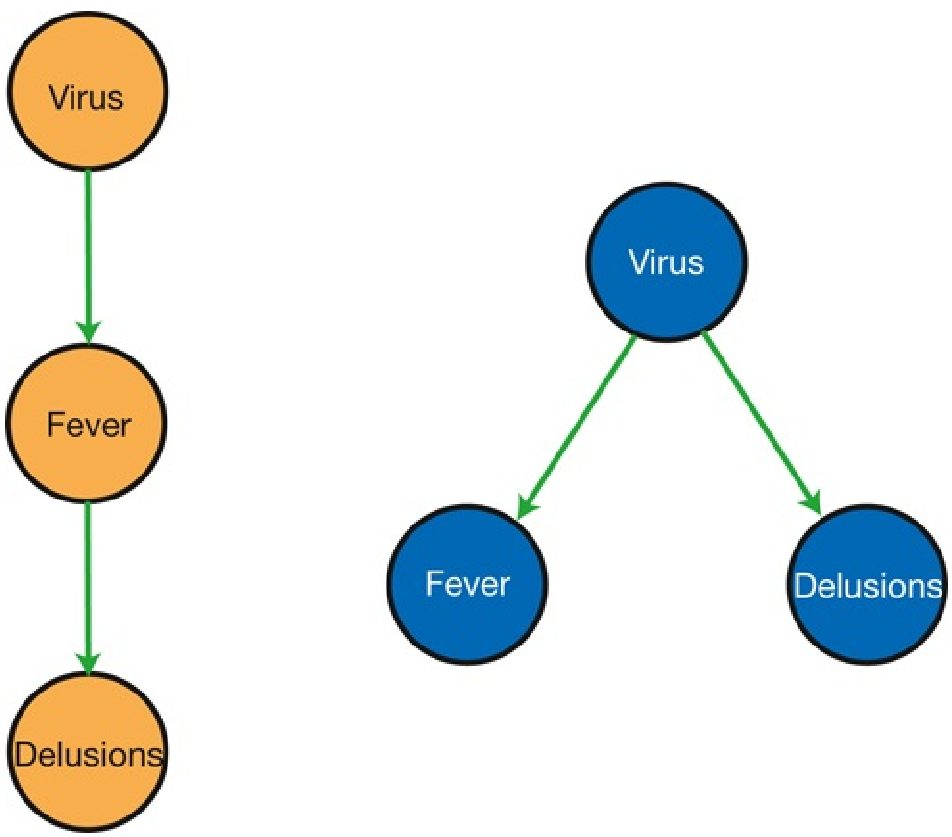

FIGURE 6.3 *Example of Two Different Causal Structures for a Virus and Two*

Symptoms: On the Left, the Virus Causes Fever, Which Then Causes Delusions; However, on the Right, the Virus Directly Causes Both Fever and Delusions

Stop and Review

A fundamental form of nondeclarative memory is conditioning. This involves learning a predictive association between two stimuli, one that is already important, and one that is learned as a predictor of the occurrence of the first. These associations take some time to be learned and can be forgotten through extinction. Phenomena like spontaneous recovery and savings illustrate that after extinction/forgetting has occurred there is still some association deep in memory. An example of an effect of conditioning of this type in human memory is the mere exposure effect. More recent work in this area has investigated how people learn cause and effect relationships in the world.

STUDY IN DEPTH

A study by Taylor and Ahn (2012) is an example of the correspondence between studies of causal learning and studies of more traditional conditioning. In this research, for some conditions, Taylor and Ahn had 80 people participate in an internet study. The purported task was for people to understand how certain medical conditions might be related to one another.

In this study, people learned that sick patients have an imaginary condition called Burlosis, which is associated with having another imaginary condition called Caprix. This was done by presenting descriptions of 20 “patients” who often showed evidence of these two conditions occurring together. This information was presented in a way to lead participants to conclude that Burlosis caused Caprix. Half of the people were only told about the co-occurrence of Burlosis and Caprix, whereas the other half were given additional information about the presence of some (again, imaginary) thing called Ablique. After spending reviewing the 20 cases, all participants were then told that scientists had discovered that Ablique was a new virus. The task at this point was to assess the cases again, this time with all participants being given information about the presence of the Ablique virus, to assess whether it caused Caprix in addition to Burlosis.

What was found was that people who did not receive information about the occurrence of Ablique from the beginning were much less likely to include the presence of this virus as a causal agent in the occurrence of Caprix than people who had information about the presence of Ablique from the beginning. The explanation for this was that, for those people who initially did not receive information about the presence of Ablique, there was an initial “causal imprinting” of the Burlosis–Caprix connection. The subsequent introduction of information about Ablique was disregarded in favor of the already-held causal explanation.

This finding parallels work in classical conditioning on a phenomenon known as **blocking**, in which the prior learning of a conditioned association blocks the acquisition of any new associations for subsequent information that might occur at the same time (Kamin, 1969). More generally, this kind of work suggests that once people have an idea for “why” something happens it is difficult for them to change their minds and accept new ideas about what causes something. Instead, there is a bias to fall back on their prior causal understandings (see also the section on retraction in Chapter 8). This is less of a problem for people who have more complete information at the outset. This may be why, to some degree, people have difficulty with complicated and nuanced explanations, such as those developed more recently by science. They tend to continue to rely on their prior, simpler explanations.

PROCEDURAL AND MOTOR MEMORY

Knowledge of how to do things, such as play the piano, throw a ball, or walk, is an important part of nondeclarative memory. People have skills but do not know exactly how they acquired them. For example, just because someone is a skilled athlete does not *necessarily* mean that he or she will make a good coach. This is because much of the knowledge is unconscious and procedural. We now look at the acquisition of skills and the influence of expertise on procedural and motor memory.

Motor Memory

Once acquired, motor memories, like other memories, need to go through a process of consolidation to make them more permanent and enduring. If this consolidation is disrupted, such as by the learning of new, similar motor memories soon after the original ones were learned, then consolidation can be disrupted and the motor memory can be forgotten (Brashers-Krug, Shadmehr, & Bizzi, 1996). Motor memory consolidation is more likely to occur if people randomize their practice strategies and do not spend too much time practicing one aspect of a skill (Kim, Rhee, & Wright, 2016). Also, if there is declarative knowledge acquired prior to learning the motor skills, this declarative knowledge may delay the consolidation of the motor memory, making it more likely to be forgotten (Breton & Robertson, 2014; Tibi, Eviatar, & Karni, 2013). Motor memories, much like other kinds of memories, benefit from a period of sleep in which consolidation can to better occur (Kempler & Richmond, 2012).

Negative Transfer

Once a procedural or motor memory is created, its can impede the learning of new procedures or skills. With **negative transfer**, prior procedural knowledge impedes the ability to learn new things (Anderson, 2000). For example, if people have learned to drive a standard-shift car and then go to drive one with an automatic transmission, there may be some negative transfer when they try to push down on the clutch (because there isn't one). The amount of negative transfer experienced is a function of the degree of overlap between the old and new information (Woltz, Gardner, & Bell, 2000).

Memory traces for older information are well established when new information is encountered. Because these older traces are so strong, they are activated each time people try to learn something new. This activation blocks the acquisition of the new information. Understanding negative transfer is important because when people try to learn a new way of doing a task, the recurrence of prior, and now inappropriate, procedural and motor memories can cause accidents, such as when a new task is learned in the workplace (Besnard & Cacitti, 2005).

Stages of Skill Acquisition

Many of the tasks we do improve with practice. These are **skills**. Some skills are activities where expertise is widely recognized, such as being able to play a sport, play a musical instrument, or craft a best-selling novel. Most skills, however, are very mundane and you may not consider them "skills." These include activities like walking, reading, riding a bicycle, driving a car, and having a conversation.

Although a wide range of skills can be stored in nondeclarative memory, the process of skill development is similar in all of them. There are three **stages of skill acquisition**: the cognitive stage, the associative stage, and the autonomous stage. These stages are shown in Figure 6.4. These stages reflect a transition from the arduous and clumsy execution of an activity to a more easy and fluid execution. Note that this does not mean a person must necessarily be in one particular stage. It is possible for experts in a skill to spend most of their time at the autonomous stage but still have nondeclarative memory for the associative and cognitive stages. As skills develop, people make choices about which strategy to use (Bajic & Rickard, 2009).

At the beginning of a skill is the **cognitive stage**. This is the period where people consciously and deliberately go about performing the actions of the task. For example, when learning to play chess, people exert a great deal of effort trying to consciously assess what is going on to keep the game progressing and either not get wiped out or, better yet, defeat the opponent. This often takes the form of comparing the current state with the desired state and taking whatever action brings one closer to the desired state.

After spending some time in the cognitive stage, people move on to the **associative stage**. At this stage they can more quickly retrieve the knowledge needed to do the task. That is, memories become directly associated with different aspects of the skill. The need to mentally verbalize or to think things through is less necessary. Information is quickly and easily retrieved, although some deliberate and conscious effort is still needed. For example, a chess player would directly retrieve information about what a set of moves would entail, and different alignments on the board begin to be viewed as offensive or defensive.

After more practice with a skill, people move to the final, **autonomous stage**. In this stage the execution of a skill has become more proceduralized and moves from involving consciousness to being largely unconscious. That is, memories and knowledge have moved from being dominated by declarative knowledge to being dominated by nondeclarative knowledge. This is seen in cases where people learn a motor skill, such as playing a musical instrument. When people become experts, the execution of various components are done with little conscious involvement other than the desire to execute a particular series of moves. There is less overt, conscious involvement in the execution of the smaller steps of the skill.

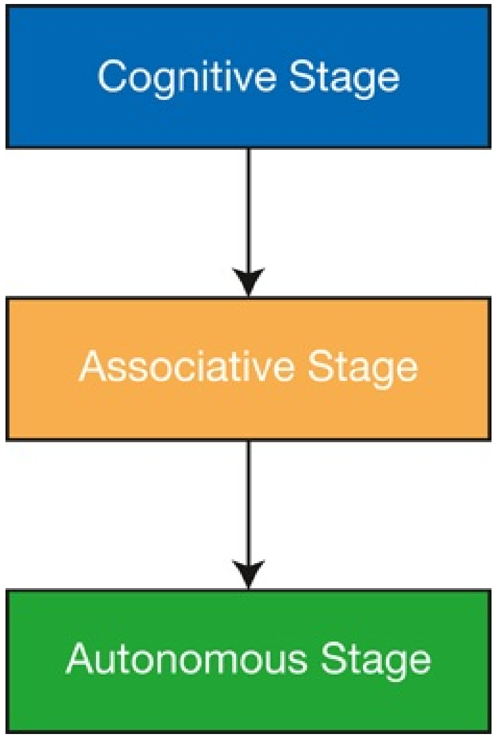

FIGURE 6.4 *The Three Stages of Skill Acquisition*

Triarchic Theory of Skill Learning

Another way of thinking about skill acquisition is Chein and Schneider's (2012) **triarchic theory of skill learning**. This view is more grounded in neurophysiological evidence at different levels of skill. As illustrated in Figure 6.5, the three types of skill processing in this model are (1) the metacognitive system, (2) the cognitive control network, and (3) the representation system. All of these systems are assumed to be engaged during skill execution, although the level of dominance of each system varies with skill level.

The **metacognitive system** is most engaged when people are first learning a skill. This system involves conscious deliberative thought and action and is devoted to processing information in more novel contexts, as is the case early on in skill acquisition. This system involves the anterior prefrontal cortex (BA 10), along with other brain areas, to reconfigure the pathways and processing in the brain to adapt to the new skill. This system can do what it needs to do quickly, although the results are not immediately long-lasting.

The **cognitive control network** becomes more engaged as people become more skilled. This system is devoted to managing the process of the skill and making its execution more automatic. This network is composed of several brain areas working together, particularly the dorsolateral prefrontal cortex (BAs 9 and 46), the anterior cingulate cortex (BAs 24, 32, and 33), the inferior frontal junction, and the posterior parietal cortex (BA 7). This network takes longer to develop than the processes in the metacognitive system, however it is more enduring.

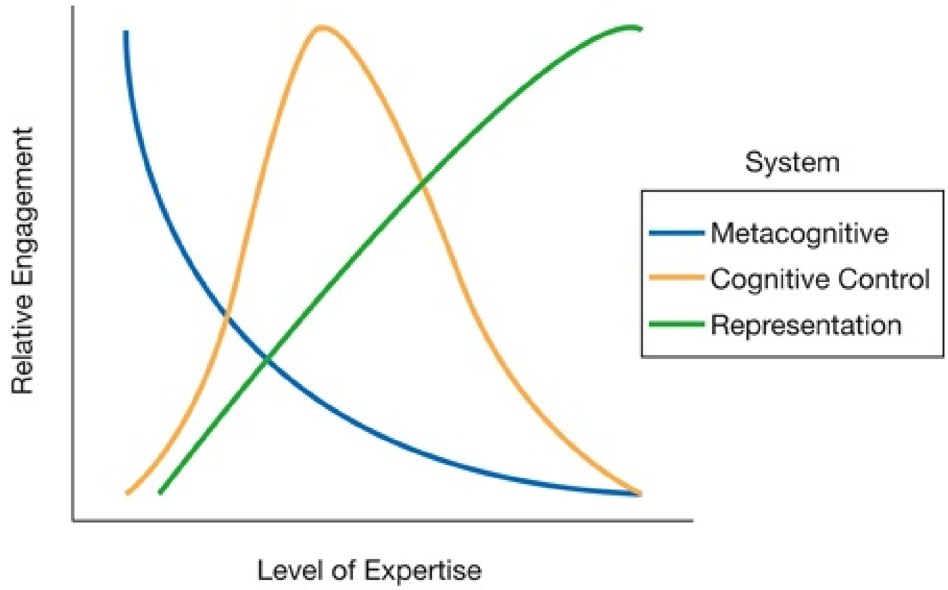

FIGURE 6.5 *The Relative Influence of the Three Neurological Systems in the Triarchic Theory of Skill Learning*

Adapted from: Chein, J. M., & Schneider, W. (2012). The brain's learning and control architecture. *Current Directions in Psychological Science*, *21*(2), 78–84

Skill performance is dominated more by the **representation system** with further practice. As people do the skill over and over, the cell assemblies in whatever part of the brain that is relevant become increasingly wired together. The memory traces in the representation system are the direct mental instructions for how to do the skill. The mediation from the other systems is less and less involved. Thus, the skill becomes even more automatic. Because the parts of the brain involved can vary depending on the nature of the skill, the whole brain needs to be considered as the site of this system. Also, in contrast to the cognitive control network, which is more domain-independent, the representational system is domain dependent. That is, these skills are represented very specifically and transfer to other domains is unlikely. For example, the skill that you developed in your automobile driving does not transfer over to your tennis swing. This network takes a very long time to develop but its processes are extremely long enduring.

Choking Under Pressure

Typically, the automation of skills in memory is helpful. However, there are cases where it can have the opposite effect. This occurs when people try to consciously think about what they are doing when the skill is highly automatized. An example of this is when players succumb to the pressure of the moment and do worse that they would otherwise. The athletes' conscious thoughts about what they are doing intrude on and conflict with the automatic processes from procedural memory (Beilock & Carr, 2001). This is known as **choking under pressure** because skilled experts often don't spend much effort consciously thinking about the mechanics of what they are doing. However, when they are in a high-pressure situation, they may start to do this and the conscious thoughts compete with the nondeclarative ones. This competition reduces performance. At a low level of skill (novices), people perform better if they focus on accuracy, whereas at a high level of skill (experts) people do better if they focus on speed (Beilock, Bertenthal, McCoy, & Carr, 2004). These performance differences between experts and novices are shown in Figure 6.6.

It is important to note that not all forms of choking under pressure are the same (DeCaro, Thomas, Albert, & Beilock, 2011). In the form discussed here, where the task primarily involves nondeclarative memory, such as putting a golf ball, people are more likely to experience choking under pressure when they have **monitoring pressure** that focuses on how they are doing the skill (e.g., knowing that you are being videotaped). Here there is a conflict between more conscious, deliberate, declarative and more unconscious, automatic thoughts.

In comparison, there can be pressure for more declarative memory tasks. An example of this might be when people take a mathematics exam. In this circumstance, people are more likely to choke under pressure when they have **outcome pressure** that focuses on the outcome of their performance (e.g., knowing that your GPA depends on how well you do on the exam). Here, people experience anxiety, and this anxiety fills working memory with irrelevant information (see Chapter 5). This reduces functional working memory span and compromises the ability to think effectively. As a result, people perform worse than their actual knowledge level.

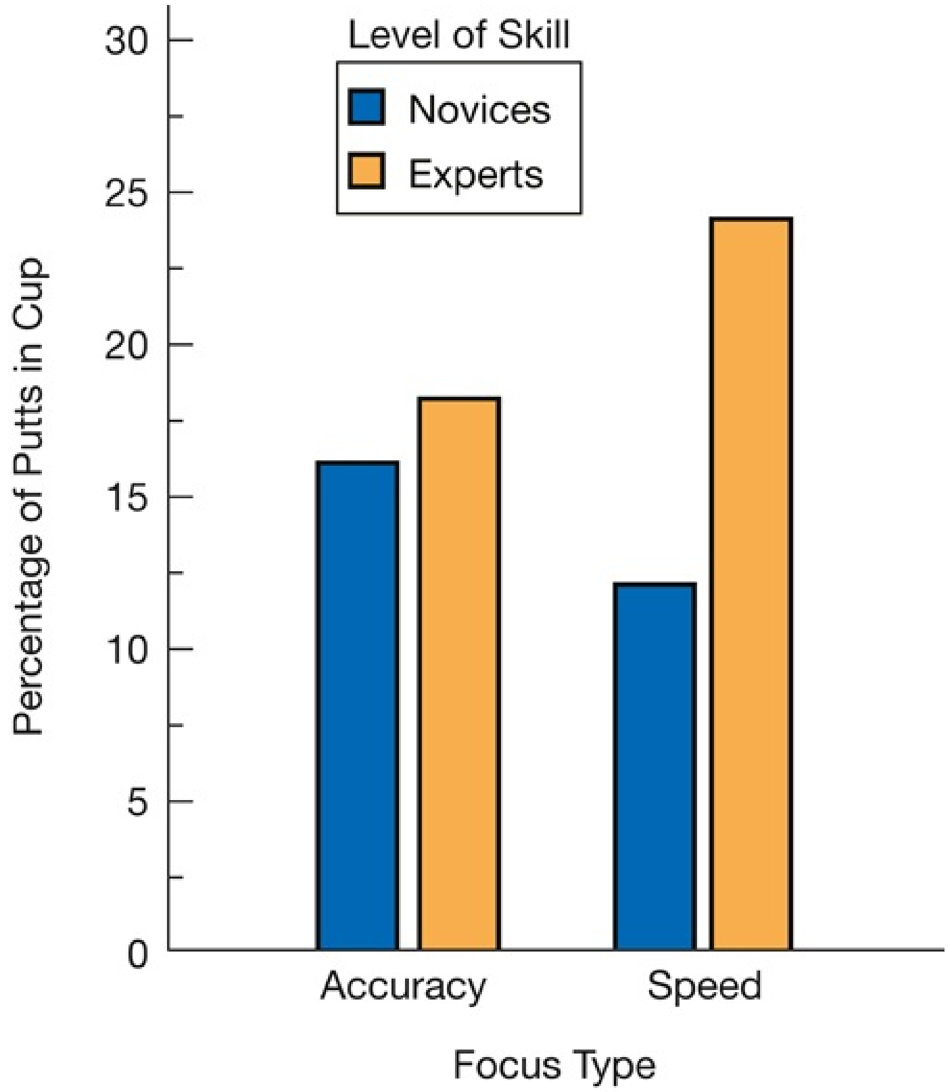

FIGURE 6.6 *Mean Percentage of Putts Made for Novices and Experts as a Function of Whether They Were Instructed to Focus on Accuracy or Speed*

Adapted from: Beilock, S. L., Bertenthal, B. I., McCoy, A. M., & Carr, T. H. (2004). Haste does not always make waste: Expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. *Psychonomic Bulletin & Review*, *11*, 373-379

The Nature of Expertise

It is clear that expertise at a task is something that takes time to emerge. But is practice sufficient to become an expert? Does talent or some other predisposition play a role as well? There is some ambiguity about this. There are some researchers who have taken the view that practice is the primary contributor to expertise (Ericsson, Krampe, & Tesch-Römer, 1993). That said, there may be differences in how people with higher and lower levels of expertise go about their practice. People who attain higher levels of expertise tend to spend more practice time on skills that they are weak at, whereas people who achieve lower levels of expertise tend to spend more practice time on skills that they are already good at (Coughlan, Williams, McRobert, & Ford, 2014).

PHOTO 6.2 *High levels of skill with a task depend on our going through a process of moving our motor memories from a slow, deliberate process, to a quicker, more automatic process*

Source: ahavelaar/iStock/Thinkstock

Improving Your Memory

One of the things that should be obvious as this point is that the more you practice and rehearse something, the better your memory will be. This is just as true for nondeclarative memories, such as motor skills like playing a sport, as it is for declarative memories, such as remembering what you learned in class. However, a point that is often overlooked when thinking about practice is that it takes time for the memories to seep in and become permanent. That is, all kinds of memories need some time to consolidate. So, when you are trying to learn something new, such as a skill, occasionally take a break from practice and allow the memories to become more permanent. These breaks can take the form of simply stepping away from the task for a few minutes or hours, taking a nap, or getting some sleep and practicing some more the next day. So, while practice does make perfect, it is better that you do not do it all at once. Take breaks and give your memories a chance to become permanent.

While extensive practice is necessary, there are other factors, such as a basic level of intelligence or genetic predispositions, that can contribute to the achievement of high levels of expertise (Campitelli & Gobet, 2011; Hambrick & Tucker-Drob, 2015; MacNamara, Hambrick, & Oswald, 2014). There is some mixture of nature and nurture when it comes to whether a person will achieve a high level of expertise in a skill.

Stop and Review

Procedural memory is nondeclarative memory for how to do things. Some of this involves motor memory for how to execute physical tasks. The acquisition of such memories is harder if there exists a prior skill memory that is similar, thereby producing negative transfer. Skills start out in as conscious, declarative memories but with practice they become more automatic procedural memories. People start at the cognitive stage, move to the associative stage, and finally reach the autonomous stage. An alternative view is the triarchic theory, in which the metacognitive system, cognitive control network, and the representation system are always involved, but that there is variations with which these systems dominate as skill level increases. At high levels of skill, conscious awareness can actually disrupt memory, leading one to choke under pressure. High levels of expertise are a result of extensive appropriate practice, in conjunction with some innate traits.

IMPLICIT MEMORY

The last form of nondeclarative memory examined here is implicit memory. **Implicit memory** is any form of memory that does not require consciousness and can operate without a person being aware that memory is being used. For example, some accounts of déjà vu attribute the odd feeling of familiarity one has with a new situation to unconscious, implicit memories of different but similar experiences (Brown, 2003; Cleary, 2008). Also, the idea of intuition appears to rely on implicit memory because it is an unconscious feeling about something. For example, if people are given word triads, such as “dream,” “ball,” and “book,” or “salt,” “deep,” and “foam,” they intuitively know that the first three do not go together, but the second three do (they are related to a fourth concept: sea), even if they consciously do not know why (Topolinski & Strack, 2009). As a general note, it is important to keep in mind that although some learning and memory may be implicit and unconscious, with extensive practice this knowledge may eventually bubble up to consciousness and become more explicit (Goujon, Didierjean, & Poulet, 2014).

In some sense, the other forms of nondeclarative memory can manifest themselves as some type of implicit memory. For example, procedural memories can be implicit, such as knowledge of how to walk. The concept of savings, as originally described by Ebbinghaus, is a form of implicit memory in which people are unaware of how previous, unconscious memories are influencing later learning (Nelson, 1978). This section considers how knowledge gets into memory without awareness, how implicit memory is assessed using **indirect memory tasks**, the differential effects of data-driven and conceptually driven processes on implicit memory, and the unconscious learning of sequential orders.

Incidental Learning

We have already discussed implicit memory in terms of encoding in Chapter 3.

People learn things either explicitly (intentionally trying to learn them) or implicitly (incidentally learning them). Incidental learning is a form of implicit memory because people are not consciously aware that the knowledge is being stored in memory. Although it is difficult to observe incidental learning as it is happening (because it's incidental), neurological measures can provide some insight into what will and will not be remembered later. EEG recordings show that information that is remembered later involves increased theta band synchronization and decreased alpha band synchronization (Klimesch, Doppelmayr, Russegger, & Pachinger, 1996). Moreover, people who remember more show more alpha band change in the lower half of the band, whereas people who remember less show more desynchronization in the upper alpha band.

Much of the tacitly acquired information from incidental learning makes up the contents of implicit memory. That is, the influences that are exerted on our thoughts and behaviors by implicit memory rely on knowledge that was unconsciously acquired. For example, people moving to a new part of the country may start altering their speech patterns to conform to the local accent. This occurs without people being explicitly aware of speaking with the new accent. You may have noticed this in your own experience. If you've gone away to college, you may find that the way you speak when you are at school differs from the way that you speak at home.

Indirect Tests of Memory

It is difficult to clearly understand what implicit memory is and does because its operations and effects are largely unconscious. To see its effects, people must show an influence of prior experience (memory) without a conscious awareness of doing so. Thus, we need an indirect way to test memory. There are a number of indirect memory tests, some of which are examined in this section. Most of these tests focus on verbal memory. However, some nonverbal tasks are described as well.

An extensively used form of indirect memory testing is **priming**. Priming occurs when people are faster and/or more accurate at retrieving target information that has been facilitated by an earlier prime trial (Tulving & Schacter, 1990). There are different types of priming but here we focus on the most basic: repetition priming. **Repetition priming** is when people are better at responding to an item that was encountered recently. This occurs even if people are unaware that they are using their memory. For example, if you saw the word "assassin" earlier, you will recognize it faster and more accurately when you see it again later. Repetition priming is larger when the information is presented in the same way it was encountered. For example, people have a better memory for rotating objects if the objects are rotating in the same direction as the first time they saw them (Liu & Cooper, 2003). This suggests that even seemingly irrelevant details about things in the world can influence memory later.

The amount of benefit a person gets from repetition priming depends on how the information was learned in the first place. Let’s look at memory for information read in a book (Raney, 2003). If repetition priming operates, people will show a benefit by reading the text faster the second time. However, the nature of this priming can vary. Suppose a reader is relying primarily on memory of the text itself (such as surface form or textbase memory). This can occur in situations where people do not comprehend what they are reading and so do not build adequate mental models of the described event. Under these conditions, repetition priming is more likely to be affected by perceptual characteristics, such as the handwriting used, the font style, or the word order. In contrast, if readers understand what is being read and are able to build adequate mental models, repetition priming extends to other texts that refer to the same state of affairs. Moreover, this repetition priming is less influenced by the perceptual properties.

One of the interesting things about priming is that it involves a decrease in neural activity in some brain areas, depending on the type of priming (Schacter & Badgaiyan, 2001). Repetition priming is associated with decreased activity in the visual cortex, whereas semantic priming is associated with decreased activity in the frontal lobes. This decreased neural activity reflects the lower amount of work that must be done because those memory engrams are already at a heightened level of availability based on the recent experience.

Indirect memory tests, such as repetition priming, influence multiple levels of representation (see Chapter 7). For example, people respond faster to words that were seen in a word list than words seen in a paragraph. However, people read a passage of text faster if that same text had been read earlier, but not if they see the same words out of context, such as in a word list (Levy & Kirsner, 1989). This suggests that, in order to have repetition priming, the appropriate level of representation needs to be retrieved. Retrieving the wrong kind of memory is less helpful.

Similarly, in a study by Oliphant (1983) the first occurrences of repeated target words were presented either in the context of the study (as is normally done) or as part of the instructions. Repetition priming was observed when the target word was in the study itself (the standard condition) but not when it was in the instructions. This suggests that memory is compartmentalized. It may be influenced by how we parse up the world, even at an unconscious level. This finding suggests that some implicit memory processes, like priming, may not cross event boundaries. That said, this effect may be limited to common, high-frequency elements of an experience and may not apply to unusual, low-frequency elements (Coane & Balota, 2010).

In a profound demonstration of indirect tests using reading, a study by Kolers (1976) had people first read a series of texts. These texts were presented in either a normal font or by inverting the letters. An example of an inverted text is shown in Figure 6.7. People were asked to read the same texts again more than a year later. It was found that people read these texts faster the second time, both for normal and inverted texts, even after a substantial degree of forgetting had occurred. Thus, not only were the words and ideas of the text remembered but even nominally superficial characteristics, such as the orientation of the letters, were stored in memory, producing savings that made later reading easier.

Many indirect memory tasks involve having people reconstruct partial or degraded information in some way. The idea is that if people have this information in memory, even at an unconscious level, they should find it easier to do this reconstruction. One example of this is a **word-stem completion** task (Graf, Mandler, & Haden, 1982). In this task people are given the initial few letters of a word (the "stem"), with the task of completing it with the first word that comes to mind. People are more likely to complete these stems with words they had seen recently, even though they are unaware that they are using prior knowledge. This isolation of implicit memory processes can be shown by using methodologies such as the process dissociation procedure (see Chapter 3) (Toth, Reingold, & Jacoby, 1994).

Another reconstruction indirect memory task is **word fragment completion**. For this task, people are given words with missing letters, such as A _ _ A _ _ IN, and are to complete them. Again, people do better if they have seen the words recently (Tulving, Schacter, & Stark, 1982). Moreover, as shown in Figure 6.8, this ability remains stable even after a long delay, whereas more conscious and explicit recognition memory continues to decline over time. This illustrates the enduring influence of implicit memory processes on behavior.

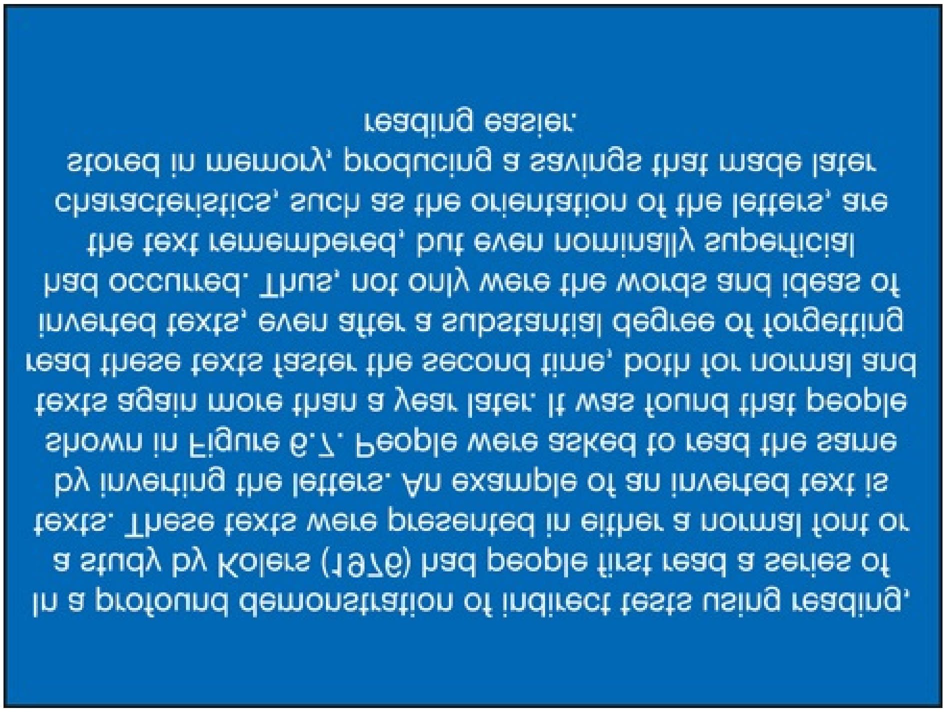

FIGURE 6.7 *Inverted Text*

Adapted from: Kolers, P. A. (1976). Reading a year later. *Journal of Experimental Psychology: Human Learning & Memory*, *2*, 554–565

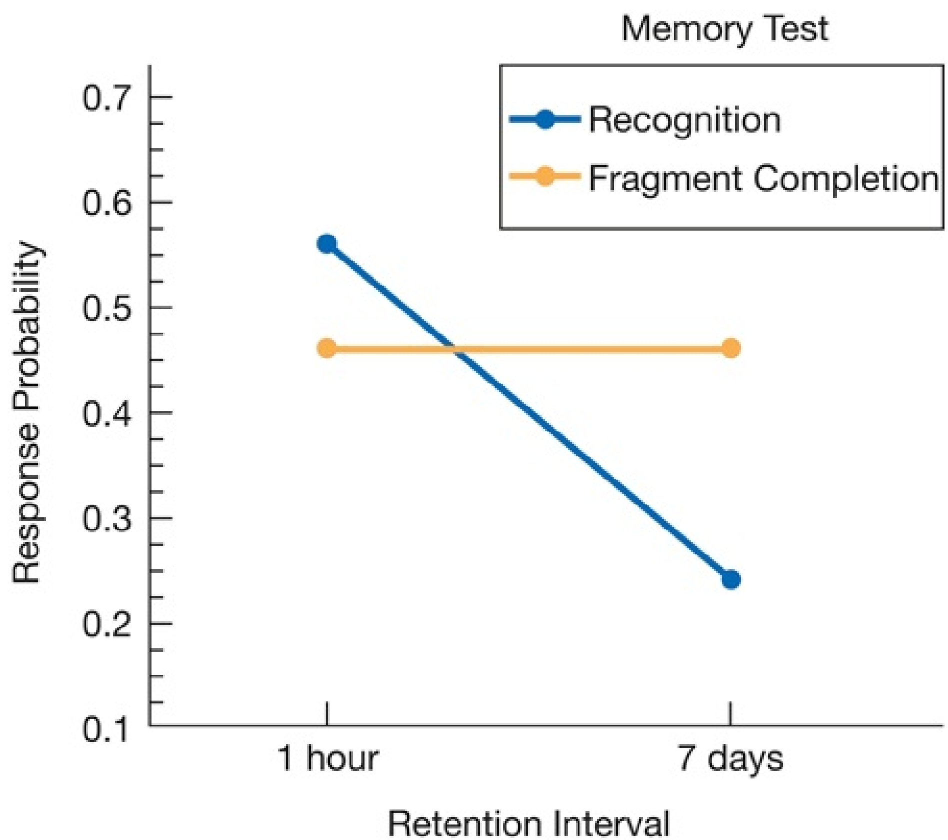

FIGURE 6.8 *The Enduring Influence of Implicit Memory (Word Fragment Completion) Relative to Explicit Memory (Recognition)*

Source: Tulving, E., Schacter, D. L., & Stark, H. A. (1982). Priming effects in word-fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *8*, 336–342

Another indirect memory test that involves reconstruction is anagram solution (Srivinas & Roediger, 1990), in which people are given anagrams, such as "tderhun" for the word "thunder." People are better at solving the anagrams if they were exposed to the word recently than if they were not. Again, people are not consciously using memory to help them solve the anagrams.

Another verbal indirect memory task is **lexical decision** (Duchek & Neely, 1989). For this measure, people are given a string of letters with the task of indicating whether it is a word or not (hence the term *lexical decision*). What is often of interest is how fast people respond to words depending on what occurred earlier. People respond faster when they have been exposed to the word recently or to words that are related to ideas they have been thinking about recently. Similar effects can be observed with a **naming** task, in which people simply name aloud, as quickly as possible, visually presented words

(Hashtroudi, Ferguson, Rappold, & Chrosniak, 1988). Words are named faster if they were seen recently or were unconsciously activated by thinking about related concepts. A more everyday influence of this is that you are more likely to say a word if you have heard it recently than if you have not.

Indirect memory is also seen when perceptual clarity is compromised. For example, imagine that a word is presented for only a fraction of a second, such as for 35 ms. Under these conditions, it is very difficult to consciously identify the word. However, if people have previously been exposed to it, then **perceptual identification** is enhanced (Jacoby & Dallas, 1981). That is, it is easier for people to identify what they see if they had seen it recently. This process can also be seen in pop music. Sometimes song lyrics are unclear and you have to guess what the singer is saying. However, if you *read* the lyrics first, you can easily follow them the next time you hear the song.

TRY IT OUT

For this Try It Out section, we focus on a task that reliably exhibits effects of unconscious nondeclarative memory, namely word fragment completion (see Neath, 1998). Ideally you should have at least 24 participants. This study is broken down into two parts. For the first part have half of the people go through a list of 20 words printed on index cards, whereas the rest do something completely unrelated. Below is a list of words used by Tulving et al. (1982). Pick 20 of these. Be sure to include all of the letters in the word and not use the italicization shown here. What your participants should do is rate each word for pleasantness. That is, how pleasant the words are to them. After going through the entire list, have people spend 10 minutes doing some distractor task. This can be any task that does not refer to the words that they just rated (such as solving math problems, sorting decks of cards, circling the letter “h” in a page from a magazine article, etc.).

The second half of the study involves both groups of people. Present people with a list of 60 word fragments. These are the words listed below. You should remove the letters that are in italics below and replace them with blank spaces. The task is to complete those words. It is important that you *do not* tell the one group that these words are related to the ones that they rated earlier. These words should be presented in a random order, with the only constraint being that the 20 words you used in the first half of the study do not be in any of the first 10 fragments. You should find that the people who originally rated the words for pleasantness should be more likely to complete those 20 fragments than the people who did not originally see those words.

AGNOSTIC	ANTENNA	ANTIQUE	ASSASSIN	BASILICA	BAYONET
BOURBON	BROCCOLI	CASHMERE	CHASSIS	CHIMNEY	CHIPMUNK
CONIFER	CUTLERY	DELIRIUM	DINOSAUR	ELECTRON	ELLIPSE
EPITAPH	FASCISM	GAZELLE	GRANARY	HAYLOFT	HORIZON
HYDRANT	INFERNO	ISTHMUS	JAMBOREE	KEROSENE	LACROSSE
LECTERN	LEPROSY	LETTUCE	LINEAGE	MARTINI	MASCARA
MYSTERY	NIRVANA	NOCTURNE	OBELISK	OCTOPUS	PARANOIA
PHOENIX	POLLIWOG	QUARTET	RAINBOW	RHOMBUS	ROTUNDA
SAPPHIRE	SEQUOIA	SHERIFF	SURGEON	THEOREM	TWILIGHT
UNIVERSE	VENDETTA	VERMOUTH	WARRANTY	YOGURT	ZEPPELIN

Although many of the indirect memory tasks use verbal materials, implicit memory is important for all types of information. An example of a nonverbal indirect memory task is priming for pictures of possible and impossible objects (see Figure 6.9). First, people view a set of objects as part of some task, such as judging whether an object faces left or right. Then they are asked to make possible–impossible decisions. Some of the objects in the second test are the same as those first test. The degree to which people respond faster and more accurately to old objects relative to new ones is an indicator of priming. Nonverbal priming for these pictures occurs only for possible objects and not for impossible objects (Ratcliff & McKoon, 1995; Schacter, Cooper, & Delaney, 1990). This suggests that memory takes into account an understanding of the object as a whole and not just the parts that make up the image.

The influence of implicit memory can also be seen with odors. Holland, Hendriks, and Aarts (2005) had students at Radboud University take a lexical decision task in a room either with a citrus-scented cleaner in a cupboard (out of sight), or with no cleaner (control condition). This odor prime led people to respond faster to cleaning related words (e.g., *poetsen*, the Dutch word for “cleaning”) on a lexical decision task. So, implicit memory has a multimodal and pervasive influence on how we think.

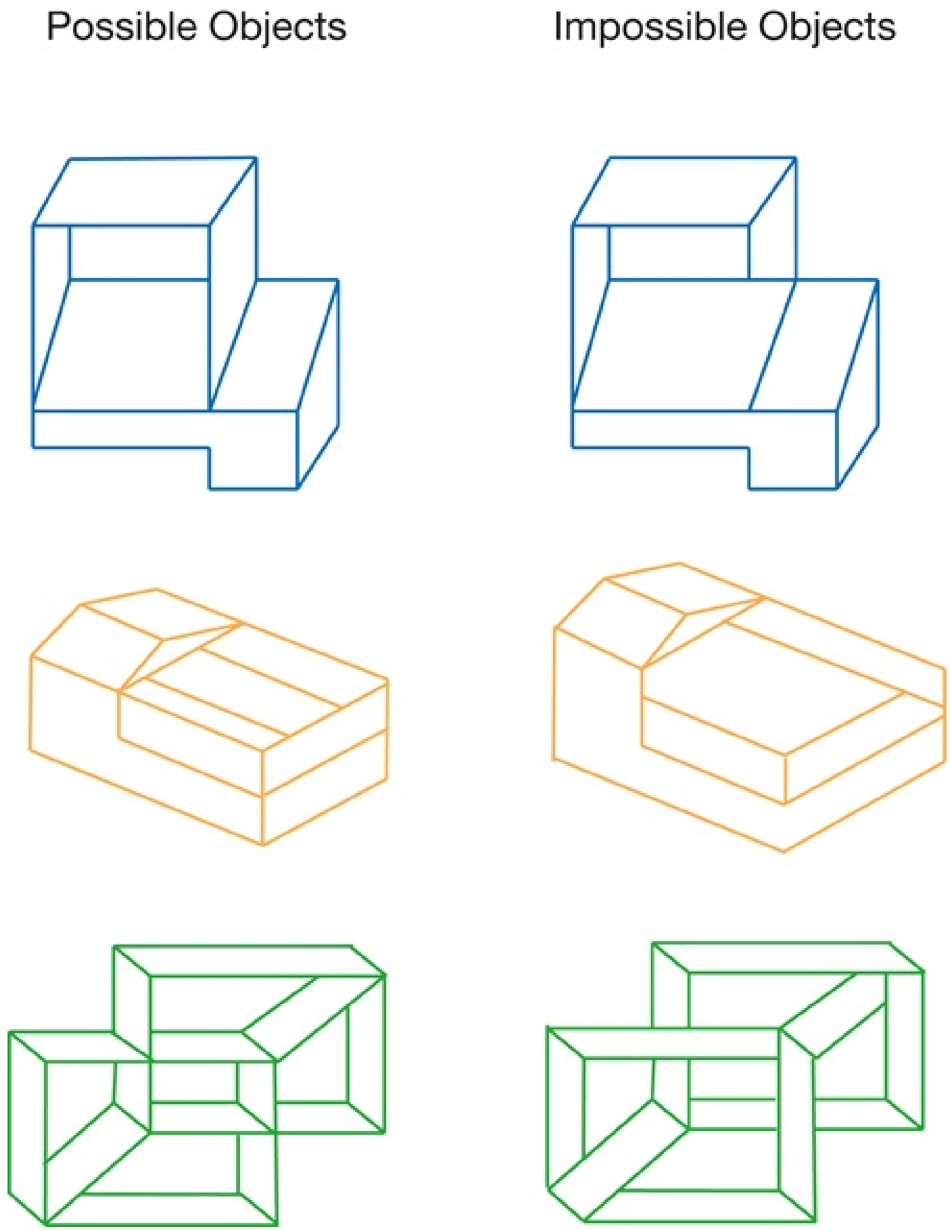

FIGURE 6.9 *Examples of Possible and Impossible Objects*

Source: Ratcliff, R., & McKoon, G. (1995). Bias in the priming of object decisions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(3), 754

Implicit memory works on us in many ways, even for information that we are unaware of. For example, Kunst-Wilson and Zajonc (1980) subconsciously presented a set of randomly generated geometric shapes to people for only 1 ms. At some point later on, people were given a forced choice recognition test to select which objects were seen earlier. Remember that for a forced choice recognition test people must select one item from a set of two or more, much like a multiple-choice test. In this situation people performed above chance. That is, they selected the previously seen shapes more often than if they were just guessing. This is interesting because they had no conscious awareness of having seen the shapes before, and conscious identification of the shapes later was at chance levels.

Data-Driven and Conceptually Driven Processes

Although the distinction between explicit and implicit memory is complex, a number of attempts have been made to describe the differences between them. One of the more successful of these is the idea that implicit memory tends to be driven more by the perceptual characteristics. This is referred to as data-driven processing because the mental activity is driven more by information in the environment (the data) than the contents of thought. In contrast, explicit memory is driven more by the conceptual characteristics. This is referred to as conceptually driven because the mental activity is driven more by prior knowledge, expectations, and goals. As an illustration, seeing a cloud in the sky as a cloud is an example of data-driven processing, but seeing shapes (such as a bunny) in the clouds is an example of conceptually driven processing.

Generally, implicit memory is more affected by the way the information was originally presented—for example, written or oral. Thus, implicit memory is more influenced by data-driven processing. In contrast, explicit memory is more affected by the amount of processing that was done during encoding, such as whether it was generated or not. Thus, explicit memory is more influenced by conceptually driven processing (Blaxton, 1989).

Sequence Learning

Another type of knowledge that is encoded into nondeclarative, implicit memory is the order of events. These are repeating patterns of events in the world that we may not be consciously aware of but to which our implicit memory has become attuned. This was shown in a study by Nissen and Bullemer (1987; see also Abrahamse, Jiménez, Verwey, & Clegg, 2010, and Fu, Fu & Dienes, 2008). In this study, students saw a row of four lights, with a button below each light. The task was to press the button below a light *after* it lit up. There were two groups in this study. In the random order, control group, the lights came on in a random order throughout the study. In the experimental group, the lights came on in a consistent 10-light sequence. It was discovered that the speed with which people pushed the buttons increased (i.e., response time decreased), with even very little exposure in the experimental group (see Figure 6.10). It is even possible to see eye movements anticipating the next item in a series (Tremblay & Saint-Aubin, 2009).

When people are asked to explicitly report the sequence they cannot (but see Wilkinson & Shanks, 2004). People were using memories for the sequence before they were consciously aware of doing so. Moreover, explicitly knowing that there will be a repeating sequence does not seems to affect performance much, if at all (Sanchez & Reber, 2013). Similar results occur in visual search tasks (looking for an object in a display) when a response sequence is repeated (Jiménez & Vázquez, 2008). While this can occur in various modalities, such as touch and vision, knowledge of the sequence does not transfer across modalities, suggesting that there is perceptual component to the memory—it is not completely action-based (Abrahamse, van der Lubbe, & Verway, 2008).

Another, more complex type of sequence learning involves the implicit learning of **artificial grammars** (Pothos, 2007). In these studies, people are given sequences of letters. These sequences are created using an algorithm such as the one shown in Figure 6.11. For example, in this case, the sequences GKGKF, LZZLF, and GKKGF are valid or “grammatical” sequences, whereas ZLFKL, KKGGF, and FZZZL are not. During an initial learning phase, people are shown a series of letter strings that were generated using the algorithm and asked to simply copy them. Even in the absence of explicit memorization, people learn not just the sequences that were seen but also the “grammar,” or production algorithm, used to generate them. This implicit memory shows itself in the ability to also accept (at above chance rates) valid sequences that were never seen before, and to accept new sequences that used different letter sets but that followed the same rules (Beesley, Wills, & Le Pelley, 2010; Reber, 1967, 1969; Vokey & Highham, 2005).

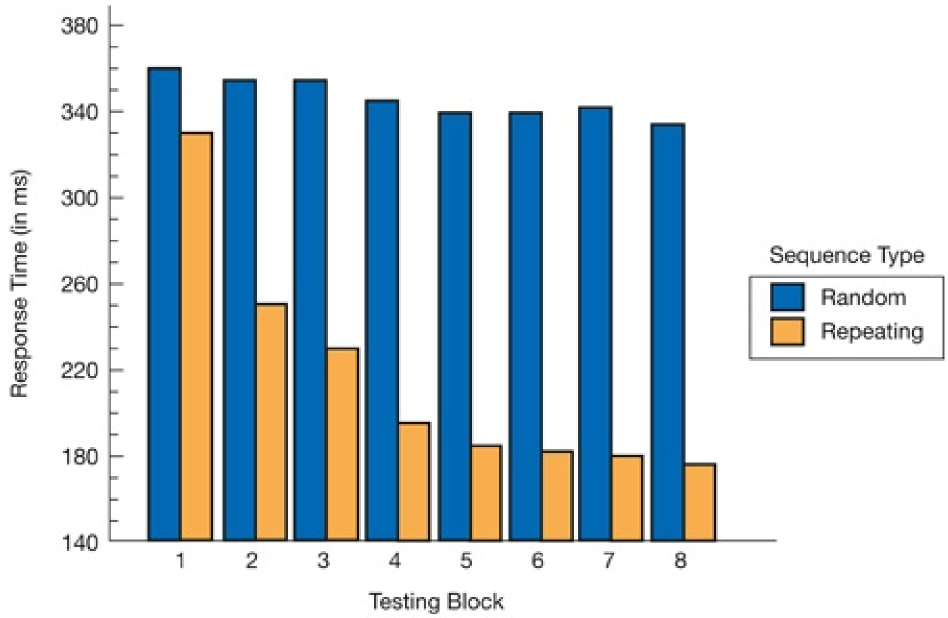

FIGURE 6.10 *Improvement on a Serial Order Task with Random and Repeating Sequences*

Source: Nissen, M. J., & Bullemer, P. (1987). Attentional requirements of learning: Evidence from performance measures. *Cognitive Psychology*, 19, 1–32

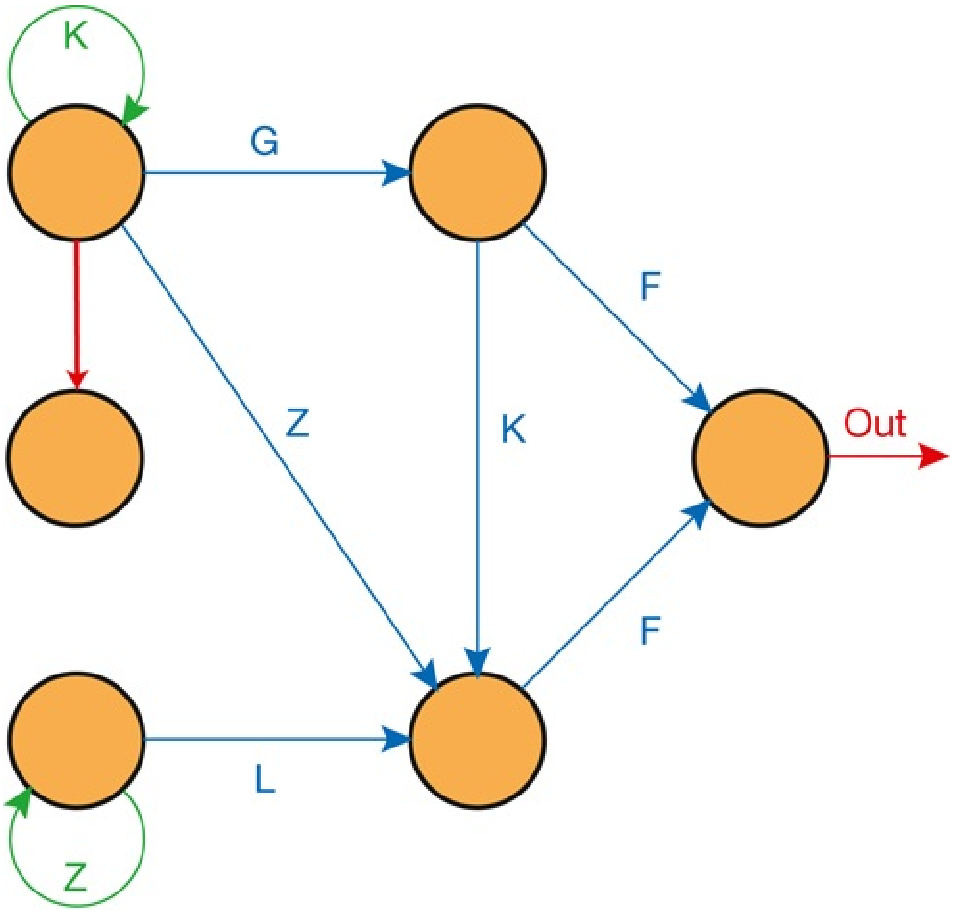

FIGURE 6.11 *Algorithm Used to Generate Artificial Grammar*

Adapted from: Reber, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behavior*, *6*, 855–863

That said, people may also develop expectations based on the structure of the individual stimuli (Pothos, 2005). That is, people may be learning bigram probabilities (i.e., the probability that a given letter will follow another) rather than an entire grammar (Poletiek & Wolters, 2009). There is some evidence that both "grammatical" rules and bigram memories are operating in these tasks (Opitz & Hofmann, 2015). Not surprisingly, the extraction of an artificial grammar is aided by neurological processes operating during sleep (Nieuwenhuis, Folia, Forkstam, Jensen, & Petersson, 2013).

Overall, artificial grammar learning seems to be a general memory process and applies not only to sequences of letters but even to completely different types of information, such as sequences of modern dance movements (Opacic, Stevens, & Tillmann, 2009) or musical tones (Tillmann & Poulin-Charronnat, 2010). It should be noted that, although this is a largely unconscious, implicit process, some conscious influences might also play a role if people become aware of the repetition (Dulany, Carlson, & Dewey, 1984). Performance is better if a person has a conscious awareness of the overarching structure of the artificial grammar (Sallas, Mathews, Lane, & Sun, 2007).

Memory Under Anesthesia

Most of the learning and memory that we have seen in this chapter has involved memory for information presented when people are conscious and aware of their surroundings. One way to study learning when people are unconscious is to look at things learned when they are under anesthesia. This is an issue of general interest. One purpose of anesthesia is to make sure people do not remember what happened during surgery (such as feeling the incision being made). However, the brain is not completely dormant under anesthesia. The issue is whether it is active enough to learn new things.

In some cases, people are read information while they are anesthetized for surgery. It might be a list of words or sentences, or a story. After surgery, people are tested to see if they have any memory for that material. Based on a review by Andrade (1995), there are many cases that have shown evidence of learning under anesthesia. This has been shown a number of ways, including a greater likelihood of producing words heard during anesthesia on category generation, free association, stem completion, ratings of familiarity, recognition, and preference ratings tasks. Some tests have also looked at more complex forms of learning, such as providing people with answers to general knowledge questions, false fame effects (Chapter 13), classical conditioning, behavioral suggestion (such as touching one's ear or chin), and therapeutic suggestions. In one study, Schwender, Kaiser, Klasing, Peter, and Poeppel (1993) had 15 patients listen to a tape of *Robinson Crusoe* while they were anesthetized and undergoing surgery. After surgery, when asked to free associate to the word "Friday," 10 of these patients responded with "Robinson Crusoe" and five did not. In contrast, none of another group of 15 patients who did not hear the novel gave this response.

PHOTO 6.3 *One of the important reasons for anesthesia during surgery is so that we don't remember what happened; however, there is some evidence that our brains do process some information and we do remember some things, although not much*

Source: herjua/iStock/Thinkstock

What people learn under anesthesia is important because it can impact recovery. It has been suggested that derogatory comments made about patients, such as commenting on an obese patient's weight, can cause them to recover more slowly. This is known as "fat lady syndrome." Some surgeons make a point of speaking about how well things are going during the surgery, even if it's not completely true, to facilitate recovery.

In general, the effects of learning under anesthesia are at an unconscious, implicit level. While this is all very interesting, it should also be pointed out that it has been very difficult to replicate many of these findings. In almost every case where studies have found evidence of memory, there are similar studies that have not. There are many reasons for this. In some cases, it may be that the data just happened to fall in such a way that an effect was observed and reported. Researchers are less likely to report *not* finding an effect, unless one has already been shown. Thus, people may have tested memory under anesthesia, not found any evidence for it, and so did not publish this finding. Alternatively, it could be that memory and amnesia effects are often very weak and difficult to measure in the first place. More recent work from neuroimaging studies has also suggested that while basic auditory and other sensory processing continues to be done by the brain while under anesthesia, more complex, interpretive perceptual processes are not functioning (MacDonald, Naci, MacDonald, & Owen, 2015), including such fundamental aspects of thinking, such as the default mode network (DMN) (see Chapter 2) This calls into question any findings based on the meaningfulness of the material. Finally, it is difficult to control many factors that could influence the observed results. These include the type of anesthesia used, how deeply the patients go under, the extent of the surgery, and so on. So, as it stands, there is the intriguing possibility that there may be some nondeclarative learning when a person is under anesthesia, but at this point it is unclear when this happens and to what extent.

Stop and Review

Implicit memory is memory that is largely outside of conscious awareness, although we may be aware of its outcomes. Incidental learning is a form of implicit memory. To test implicit memory, indirect methods look at the influence of memory without making people aware that they are using their memories. Such tasks include priming, word-stem completion, lexical decision, word naming, and perceptual identification tasks. All of these are founded on the idea that processing is biased toward recent experiences. The distinction between implicit and explicit memory can thought of in terms of a difference between data-driven and conceptually driven processing. One form of implicit memory involves unconscious sequence learning, as well as the implicit acquisition of underlying grammatical structures. Finally, implicit memory may (or may not) be operating when people are under anesthesia.

PUTTING IT ALL TOGETHER

Not all memory is conscious. In fact, most of it is unconscious. It is difficult to articulate just what this nondeclarative memory is doing. As noted elsewhere, a primary reason for having any kind of memory is to prepare you for the future. The idea of quick, efficient, and unconscious preparation for what is going to happen soon or next captures a lot of what nondeclarative memory does. You prefer things you've be exposed to before, even unconsciously. Also, the unconscious learning of sequences and artificial grammars is inherently predictive. Prediction is also seen in classically conditioned contingency relationships (this causes that). Your skills, after sufficient practice, are often nondeclarative memories for how to execute large sets of motor movements at a high level of speed and accuracy. This just would not be possible if you were to think about every little step you take next along the way. This include both specialized skills, such as playing the English horn, as well as more mundane skills such as walking and chewing gum at the same time. This is done without using much, if any, conscious mental effort. Disrupting this unconscious flow can cause you to choke.

The other big thing that nondeclarative memory does is allow you to pick up knowledge without explicitly trying to do so. Your brain is always tracking your experiences to try to understand the world. It does this without you having to devote conscious effort. Moreover, memory draws upon this knowledge and influences your behavior without bringing information into conscious awareness. This is the realm of implicit memory. You have all kinds of knowledge in nondeclarative memory that you are not even aware of. Because these memories operate below the radar screen of awareness, a number of indirect methods are needed to assess how this important part of your memory is involved in your life. These include spontaneous recovery, savings, and negative transfer phenomena, as well as changes in performance on repetition priming, word-stem completion, word fragment completion, lexical decision, and perceptual identification tasks.

STUDY QUESTIONS

1. What are the primary components of classical conditioning, and how does learning occur?
2. What are some of the important phenomena of classical conditioning?
3. How is the mere exposure effect a nondeclarative memory phenomenon? How is it a classical conditioning phenomenon?
4. In what way are studies of causal learning examples of nondeclarative memory?
5. People learn procedural tasks by learning new motor programs. How do these motor memories resemble or differ from declarative memories? How are they affected by negative transfer?
6. What are the stages that knowledge goes through to develop skilled procedural memories? How does Chein & Schneider’s triarchic theory map onto different brain networks?
7. Where does expertise at a skill come from? That is, what does a person need to have or do to become an expert at a skill?
8. What is implicit memory and how is it measured?

9. What are some sorts of effects of implicit memory that can be observed?
10. What sort of knowledge can be learned and can influence later behavior with implicit memory?
11. How is the operation of memory affected by anesthesia used in medicine?

KEY TERMS

- artificial grammars
- associative stage
- autonomous stage
- blocking
- classical conditioning
- choking under pressure
- cognitive control network
- cognitive stage
- contiguity learning
- contingency learning
- extinction
- implicit memory
- indirect memory tasks
- instrumental conditioning
- learning curve
- lexical decision
- mere exposure effect
- metacognitive system
- monitoring pressure
- naming
- negative transfer
- nondeclarative memory
- outcome pressure
- Pavlovian conditioning
- perceptual identification
- priming
- repetition priming
- representation system
- savings

- skills
- spontaneous recovery
- stages of skill acquisition
- stimulus-response association
- stimulus-stimulus association
- systematic desensitization
- triarchic theory of skill learning
- word fragment completion
- word-stem completion

EXPLORE MORE

Here are some additional readings that you can explore to give you better insight into some of the principles of nondeclarative memory.

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CHAPTER 7

Episodic Memory: Past and Future

Memories help define who we are. Our opinions, attitudes, likes, and dislikes are a result of our experiences. Memory is the repository of those experiences and the shaper of our future actions. Thus, it is important to understand our memories of the events and episodes of our lives. Memories of personally experienced events are stored and remembered in ways that have unique characteristics. Memories for events that we experienced are **episodic memories**, whereas memories for general world knowledge are **semantic memories**. An example of this distinction is the difference between remembering the last movie you saw (episodic) versus remembering what a movie is (semantic). This chapter and the next largely cover episodic memories. Semantic memories are covered in Chapter 9.

Several aspects of episodic memory are covered here. We first look at what makes episodic memory different from other types of memory. After that we consider the various types of content that can be part of an episodic memory, and how they can be used in the process of cuing a memory. This is followed by a consideration of how various types of context influence the organization and retrieval of episodic memories. We look at how different types of practice can improve memory. There is also coverage of how organization and distinctiveness, two seemingly opposite ways of thinking about information can both improve episodic memory along with a consideration of the role of adaptive memory processes. Finally, we extend the idea of episodic memory processing to events that we are likely to experience in the future. In Chapter 8 (on forgetting), some attention is given to how we lose the ability to remember events that we have experienced.

EPISODIC MEMORY AND MENTAL TIME TRAVEL

One of the hallmarks of episodic memory, according to Tulving (1983, 2002), is the ability to engage in **mental time travel**, which is associated with his idea of auto-noetic consciousness. What makes episodic memory different is the ability to mentally reinstate the context or circumstances of events and relive or replay them as we were there again. There is evidence from neuroimaging suggesting that people and animals replay events from the past, such as the previous navigation of a maze (Wilson & McNaughton, 1994). Moreover, this is the type of thinking that we do when we are mind-wandering (Corballis, 2013), and it involves the operation of the default mode network (see Chapter 2).

The bulk of the research has focused on remembering specific events from the past. However, mental time travel has also been explored in terms of thinking about future events. This is why there is a section of this chapter on memory for the future. In general, the neural systems that are involved in episodic memory, are also used in future thinking, navigation (which involves the context in which one finds oneself), theory of mind (taking other people's perspectives), and imagining fictitious worlds (as when reading a novel) (Hassabis & Maguire, 2007).

CONTENTS AND CUING

Like most long-term memories, episodic memories are amalgams of different types of information. These components can be used either as whole units or as separate pieces. For example, when you remember a birthday party, you may recall the people, food, music, and gifts. Alternatively, you may remember a conversation you had with someone at the party but have no memory of songs that were sung, what other guests were wearing, or the party decorations. Our coverage starts different kinds of information that are in episodic memory and how it is used later during remembering.

Serial Position Effects

The discussion of short-term memory in Chapter 4 introduced the serial position curve, with superior memory for things at the beginning (primacy effect) and at the end of a sequence (recency effect). Serial position curves are also seen in long-term memory, such as memories of going to the theater (Sehulster, 1989), although recency effects are larger (Hitch & Ferguson, 1991). The explanation for serial position curves in episodic memory differ from those for short-term memory. Primacy and recency effects are attributed to the distinctiveness of those positions (Healy, Havas, & Parker, 2000). In addition, the primacy effect reflects a novelty process. The first item is unusual relative to the context that preceded it, and so it is remembered better. The recency effect reflects a standard forgetting curve, with more recent events being remembered better than older events. Finally, events at the beginning and end of a sequence are less susceptible to interference (see Chapter 8).

Levels of Representation

When we experience an event, we do not think of it simply and directly. Instead, we process it at multiple levels. Each of these levels leaves a memory trace. An illustration of this is memory for text, where there are three levels of representation: the surface form, the textbase, and the mental model (van Dijk & Kintsch, 1983). The surface form captures the verbatim text. This is important initially but is usually quickly forgotten (Sachs, 1967, 1974). The textbase is an abstract represen tation of the text. For example, the sentences "the girl hit the boy" and "the boy was hit by the girl" have different surface forms but the same underlying meaning, which is captured by the textbase. At the highest level is the mental model (Johnson-Laird, 1983; Radvansky & Zacks, 2014; Zwaan & Radvansky, 1998), which represents the state of affairs described by the text, rather than the text itself (Glenberg, Meyer, & Lindem, 1987). The mental model is a mental simulation of the described events. Another way to think of episodic memories is that they often contain the who, what, when, where, why, and how of an experience. The binding of the content and context information that make up episodic memories occurs in the hippocampus. Thus, you have a mental model of the event, which also includes some perceptual or other experiential details.

In general, mental models are remembered over long periods of time. People use knowledge at this level to make memory decisions about what was encountered before (Bransford, Barclay, & Franks, 1972; Garnham, 1981). For example, people who read "the turtles sat on a log, and the fish swam beneath them" are more likely to say later that they read the sentence "the turtles sat on a log, and the fish swam beneath it" because this sentence describes the same situation.

In a study by Kintsch, Welsch, Schmalhofer, and Zimny (1990), people read a text and then took a recognition test either immediately, 40 minutes, two days, or four days later. An extension of this, with data from my own lab, with four texts and retention intervals up to 12 weeks later, is shown in Figure 7.1. The results show that the surface form memory decays rapidly. The textbase memory, although better than the surface form, continues to decline. However, memory for the mental model was relatively durable and did not show much change. As a real-life example, when you read a newspaper article you quickly forget the exact wording but remember the basic ideas in the article for a while. However, your memory for the event described in the article (what the article was about) is more enduring and is what you remember over the long term.

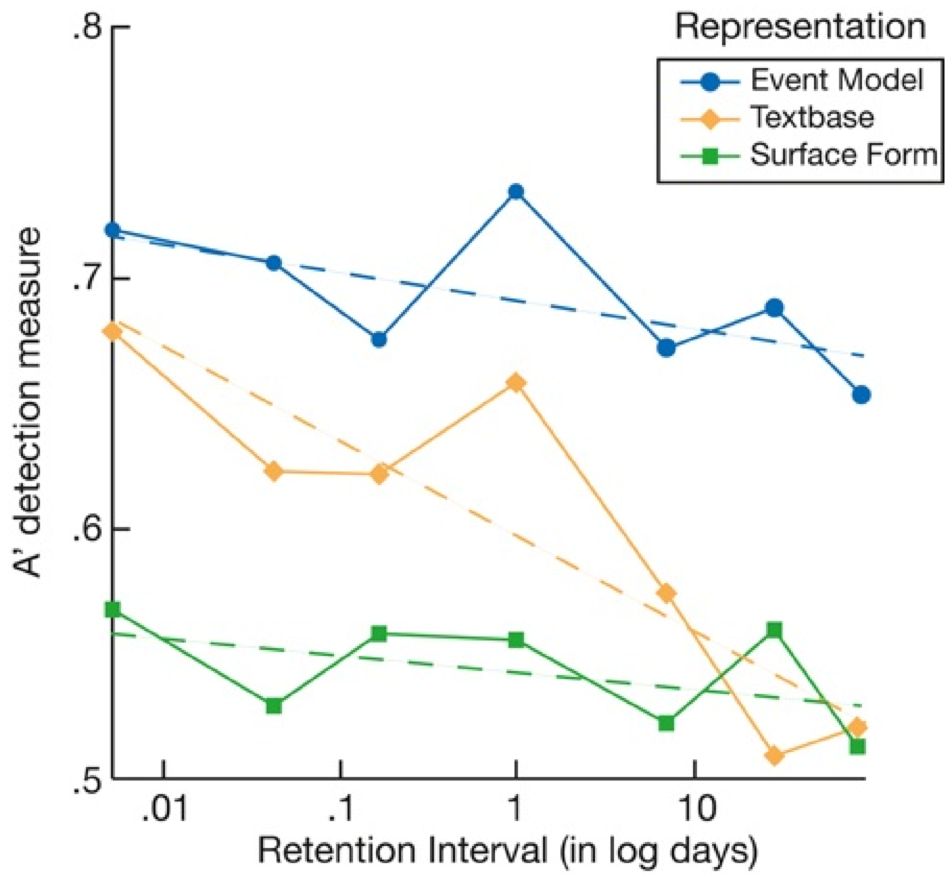

FIGURE 7.1 *Episodic Memory Retention for Information at the Surface Form, Textbase, and Mental Model Levels*

Cuing

When we recall an event, we may do so easily, but sometimes we need a prompt to direct us. This is called **cuing**. For example, you may have trouble remembering someone's name because you can't remember where you know them from. While talking to the person something is said about treating injuries and you remember that the person was a medic who treated your friend for a small cut at the county fair. The detail of treating injuries served as a cue to help you to retrieve that memory. In general, memory cues improve retrieval (Tulving & Pearlstone, 1966) by accessing memory traces that contain the same information (Bransford & Stein, 1984). Long-term memory is content-addressable, so we can access information using the components that make it up.

There are two types of episodic retrieval cues: feature cues and context cues. Feature cues are discussed here and context cues in the next section. Feature cues involve components of the memory itself. With our medic example, the treating of an injury is part of the memory that you access. It is a feature of the previous event. Features can be any component that can serve to help cue the sought after memory. That said, some features are better cues than others. For example, in memory for melodies, the timbre in which a melody was originally heard (i.e., what instrument it was played on) is a more effective cue than other aspects, such as its pitch or key (Radvansky, Fleming, & Simmons, 1995).

One of the best feature cues is yourself. This is the **self-reference effect**. If you can relate things to aspects of who you are, then your memory will be better (Bellezza, 1992; Rogers, Kuiper, & Kirker, 1977; Symons & Johnson, 1997). This self-referencing is often done spontaneously. For example, people are more inclined to remember other people’s birthdays that are closer to their own (Kesebir & Oishi, 2010). We also better remember things that we think of as belonging to us in some way (van den Bos, Cunningham, Conway, & Turk, 2010).

Odors are particularly powerful memory cues. Moreover, as discussed later, odors can be a context cue. As noted by Herz and Engen (1996), the smell of things is a good memory cue because of the ease with which odors tap into the emotional aspects of memories. This may be why some odors are strongly associated with certain emotions (think of flowers and perfumes). Herz and Engen suggest that this may be because of the strong neurological connection of olfactory parts of the cortex to the amygdala and hippocampus (only two or three synapses).

PHOTO 7.1 *Memories can be triggered by cues that are parts of those memories—some of the most powerful episodic memory cues are odors of events from our past, such as smelling cookies and being reminded of times spent with your mother as a child*

Source: Jupiterimages/Creatas/Thinkstock

It might be tempting to think that the more closely a cue matches the original memory, the more effective remembering will be. That is, the more complete the memory cue is, the better retrieval will be. While this is true, in general, it turns out that what is critical is not the degree of overlap but how diagnostic a cue is. The fewer memories a given cue corresponds to, the more likely remembering will be successful (Nairne, 2002). For example, if you have lunch in the same place every day, someone trying to remind you of an event by cuing with the place where you typically eat is not going to be very helpful because this is not diagnostic information. However, if you are cued with a place where you had lunch only once, this is going to select out just a single memory and will be more effective.

Stop and Review

Episodic memory involves mental time travel for events that are different from the current moment and that focus on individual experiences. Episodic memories are influenced by the order in which things were learned, showing a serial position curve. They also capture information at multiple levels of representation. Some of these representations are forgotten quickly (surface form and textbase), whereas others (mental models) are retained longer. Episodic memory content can serve as cues to aid remembering by selecting out individual traces for retrieval. With the appropriate cues, otherwise-forgotten memories can be brought to mind.

TRY IT OUT

In this section, we consider a demonstration of the principle of cuing. This task requires at least 12 people.

To demonstrate the effectiveness of episodic memory cuing, we'll use a method developed by Bransford and Stein (1984). First, read the list of sentences below to a group of participants. After you have read them, wait a minute and then have people try to recall as many they can. They can do this by writing the sentences down on a sheet of paper.

A brick can be used as a doorstop.
A wine bottle can be used as a candle holder.
A record can be used to serve potato chips.
A leaf can be used as a bookmark.
A newspaper can be used to swat flies.

A sheet can be used as a sail.
A bathtub can be used as a punch bowl.
A rock can be used as a paperweight.
A pen can be used as an arrow.
A rug can be used as a bedspread.
A scissors can be used to cut grass.
A balloon can be used as a pillow.
A dime can be used as a screwdriver.
A ladder can be used as a bookshelf.
A pan can be used as a drum.
A guitar can be used as a canoe paddle.
An orange can be used to play catch.
A TV antenna can be used as a clothes rack.
A boat can be used as a shelter.
A flashlight can be used to hold water.
A knife can be used to stir paint.
A barrel can be used as a chair.
A telephone can be used as an alarm clock.
A board can be used as a ruler.
A shoe can be used to pound nails.
A lampshade can be used as a hat.

When they are done, have them draw a line under the last one they were able to recall. Then read the words below and ask people to write down any additional sentences they are able to recall. You should find that people are now be able to remember more sentences. This is because the words below serve as retrieval cues for the sentences read earlier and help people access otherwise forgotten memories.

Brick; Wine bottle; Record; Leaf; Newspaper; Sheet; Bathtub; Rock; Pen; Rug; Scissors; Balloon; Dime; Ladder; Pan; Guitar; Orange; TV antenna; Boat; Flashlight; Knife; Barrel; Telephone; Board; Shoe; Lampshade

CONTEXT

In addition to the contents of a memory, another important part of what is saved in episodic memories is the context in which information is learned. There is a variety of contexts that can be bound to a memory. We'll start with the external contexts in which people find themselves. One role of the hippocampus is to bind such information together to form episodic memory traces (Ranganath, 2010). If you remember, in Chapter 2 we discussed how the hippocampus integrates information from anterior and posterior inputs. The anterior inputs correspond more to content information and the posterior inputs correspond more to contextual information.

Context is important for episodic memory because changes in context can indicate new episodic events (Ezzyat & Davachi, 2011), such as a shift in spatial location or temporal framework (e.g., a day later). Context can be a powerful memory cue and the activation of context in aiding memory retrieval is associated with activity in the parahippocampal cortex (Diana, Yonelinas, & Ranganath, 2013), part of the posterior input stream to the hippocampus.

Encoding Specificity

The influence of environmental context on memory is reflected in the **encoding specificity** principle (Thompson & Tulving, 1970). This is the superior ability to remember when the retrieval context matches the encoding context. Otherwise, the difference in context makes remembering harder because context cannot provide a retrieval cue. For example, if you learn something in one room it is easier to recall it when you are in the same room. It is not unusual to fail to remember something until you return to the room where you got the information in the first place. Smith (1988) provides a clear account of the power of encoding specificity:

> Having lived most of his life in St. Louis, Missouri, except for two years at the University of Texas at Austin, and four years in the military service during the Second World War, my father returned to Texas after 42 long years of forgetting. Although previously certain that he could recall only a few disembodied fragments of memories of his college days, he became increasingly amazed, upon his return, at the freshness and detail of his newly remembered experiences. Strolling along the streets of Austin, my father suddenly stopped and animatedly described the house in which he lived in a location now occupied by a parking lot. He recalled in vivid detail, for example, how an armadillo had climbed up the drainpipe one night and became his pet, and how the woman who had cooked for the residents of his house had informed them of the attack on Pearl Harbor, abruptly ending his college career. Not until he returned to the setting in which those long-past events had occurred had my father thought or spoken of them.
>
> (Smith, 1988, p. 13)

The encoding specificity principle is illustrated in a study in which scuba divers learned lists of words. Some lists were learned on land and others were learned under water. Later the divers were tested in either the same or a different context. As shown in Figure 7.2, memory was better when the words were recalled in the same context rather than in the different one (Godden & Baddeley, 1975).

The encoding specificity effect is quite reliable. The contexts at encoding and retrieval do not need to be identical, but need only be similar (Smith, Handy, Angello, & Manzano, 2014). Importantly, it is observed when an environment is actually present or only thought about (Smith, 1979). Thinking about prior context has some behavioral manifestations. For example, people look to a place on a computer screen where something was previously studied, even though the screen may be blank (Johansson & Johansson, 2013). Presumably people mentally reinstate a context, even if it is something as simple as a screen position. Also, although it was initially suggested that encoding specificity was stronger with recall than recognition (Smith, Glenberg, & Bjork, 1978), it operates for both (Smith & Vela, 2001). If people distract themselves from the immediate environment during learning (Smith & Vela, 2001), then encoding specificity may not be apparent.

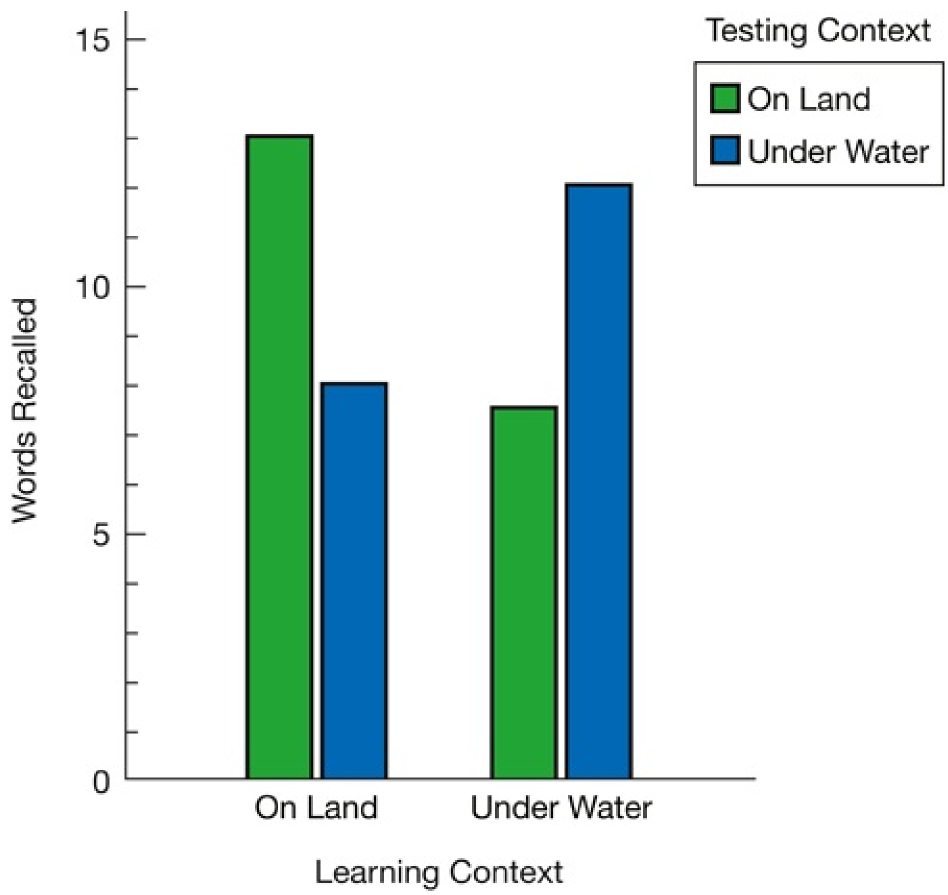

FIGURE 7.2 *Results of Study Illustrating the Effect of Encoding Specificity on Memory for Word Lists*

Adapted from: Godden, D. B., & Baddeley, A. D. (1975). Context-dependent memory in two natural environments: On land and underwater. *British Journal of Psychology*, *66*, 325–331

As a student, you may think encoding specificity means that it is better to study in the same room where you will take an exam. However, this applies the encoding specificity principle in a suboptimal way. Memories are strongly associated with a context when things are always encountered in the same one. Something that is learned in different contexts—if you study in different places—does not exhibit a strong encoding specificity influence. The information is more context-independent (Smith et al., 1978). You can use the knowledge when you need it, not just when you happen to be in the right place. Thus, it is best to not study in the same place all of time. Mix it up.

State-Dependent Memory

Concepts like context and encoding specificity may refer to external, environmental contexts, such as a room. However, there are internal contexts as well. One internal context is a person's physiological state (e.g., being sleepy, drunk, or excited). This is also stored in memory. Memory is better remembered when people are in a similar physiological state during recall as they were during learning. This is **state-dependent memory**.

An example of state-dependent memory is seen in a study in which people learned while they were sober or drunk. They then took a memory test in either the same or a different state. As shown in Figure 7.3, memory was better when people were in the same physiological state at both learning and test (Goodwin et al., 1969). If people studied while drunk, they did better on the test if they took it while drunk. (It is important to keep in mind that memory is worse overall if a person is drunk during learning or testing.) Similar state-dependent memory effects occur with nicotine (Peters & McGee, 1982), marijuana (Eich, Weingartner, Stillman, & Gillin, 1975), Ritalin (Swanson & Kinsbourne, 1976), and the physiological changes associated with aerobic exercise (Miles & Hardman, 1998).

Mood-Dependent Memory

Another internal context that can affect memory is mood or emotion. We are always in some mood. These emotional states are stored in memory, allowing for

mood-dependent memory. Memory is better if we are in the same mood we were in when we learned the information as when we try to remember it (Blaney, 1986; Bower, 1981). That is, memory for the information is dependent on the mood one was in while it was learned and remembered. So, when you are happy, you remember things better that you learned when you were happy. Say you have a fight with your boyfriend/girlfriend. While you are angry, you think of reasons why they are such a jerk (they really are, aren't they?). Later, you calm down and think about their good qualities. You are happy and think of all of the reasons why they are so nice (they really are, aren't they?). When you have another fight weeks later, all those negative thoughts come back to mind more easily because you initially thought of them while you were angry.

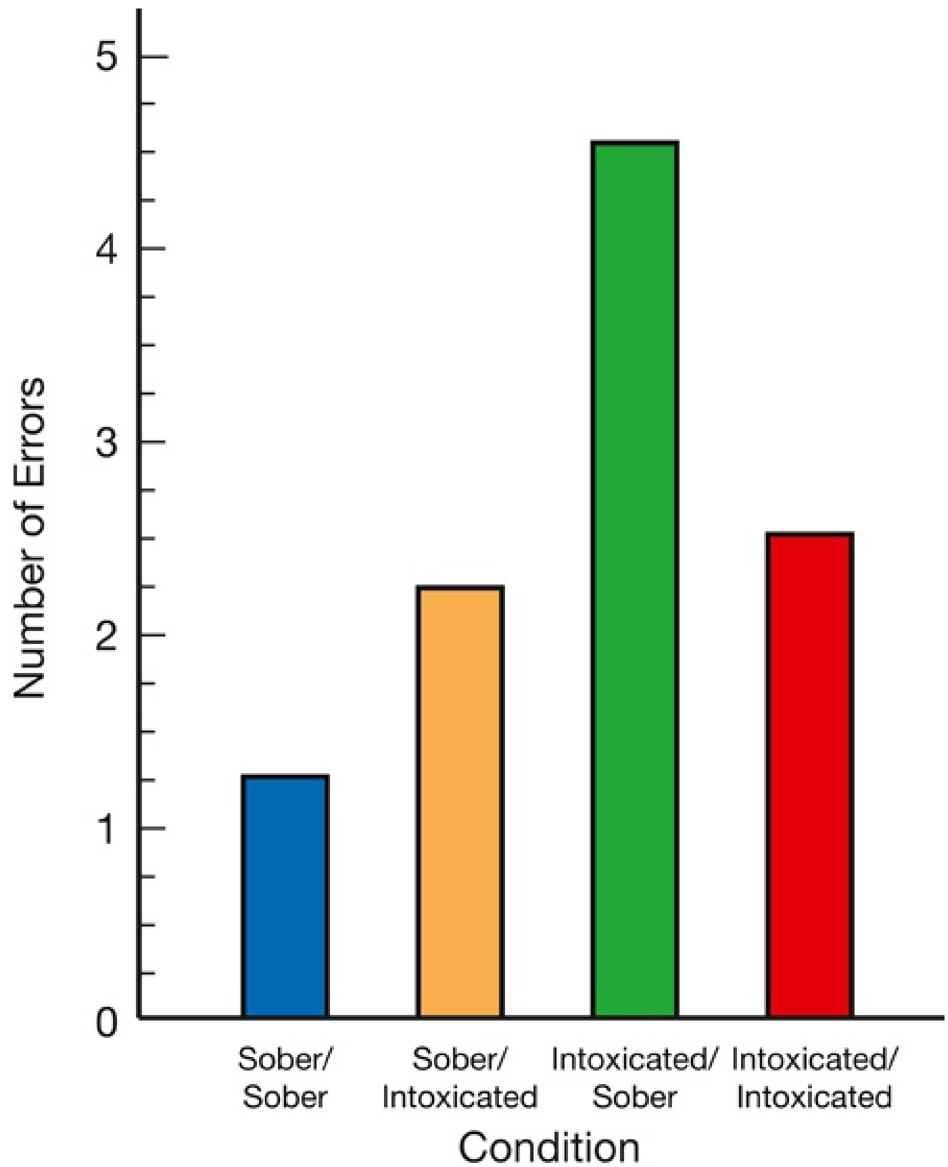

FIGURE 7.3 *Results of a Study on State-Dependent Memory and Alcohol Consumption*

Source: Goodwin et al. (1969). Alcohol and recall: State-dependent effects in man. *Science*, *163*, 2358–2360

A related concept to mood-dependent memory is **mood-congruent memory**, which is the finding that it is easier to think of things that are congruent with one's current mood. For example, a depressed mood makes it more likely that depressing ideas will be retrieved. Mood-congruent memory is supported by neurological work. Maratos, Dolan, Morris, Henson, and Rugg (2001) tested memory for words that were read in the context of emotionally positive, emotionally negative, or neutral sentences. Later, a recognition test was given during an fMRI scan. Words read in emotionally positive or negative contexts were accompanied by more activation in brain regions associated with emotion processing, such as the amygdala and orbitofrontal cortex (BA 11).

Overall, all kinds of contexts can influence episodic memory. As noted by Terry (2000), other types of context that influence memory include music, odors, temperature, time of day, body position (lying down or standing up), phone calls, and pain. Even the sound of a person's voice can be a context and can influence memory (Goh, 2005).

Transfer Appropriate Processing

Memory is also influenced by the context of people's thought processes during learning. Memory is better when retrieval uses mental processes that are more in tune with those used at learning, a principle called **transfer appropriate processing** (Kolers & Roediger, 1984; Roediger & Blaxton, 1987; but see Mulligan & Lozito, 2006). As a simple example of this, bilinguals find it easier to remember things when the language used at the time of encoding and at the time of retrieval are the same (Marian & Neisser, 2000). This principle is also related to the idea of depth of processing discussed in Chapter 3. When learning uses processing that emphasizes meaning, this has a greater positive impact on direct memory tests such as recall or recognition. In contrast, when learning emphasizes shallow surface characteristics, this has a greater impact on indirect memory tests, possibly because similar neural structures are activated when transfer appropriate processing occurs (Schendan & Kutas, 2007).

An example of transfer appropriate processing in a study by Morris, Bransford, and Franks (1977), in which students responded to words using either a meaning-based (deep-level) task, such as whether the word "plane" made sense in the sentence “The __________ had a silver engine,” or a rhyme-based (shallow-level) task, such as whether the word “eagle” made sense in the sentence “__________ rhymes with legal.” Later, students took either a standard recognition test (a direct memory test) or a rhyming recognition test (an indirect test) in which they indicated whether a new word rhymed with one that they had heard earlier (e.g., “regal”). The results, shown in Figure 7.4, reveal that memory is better when the encoding and retrieval processes match than when they do not. Thus, depth of processing is not a clear guide to future memory. Instead, how successful memory is depends on how people think about information.

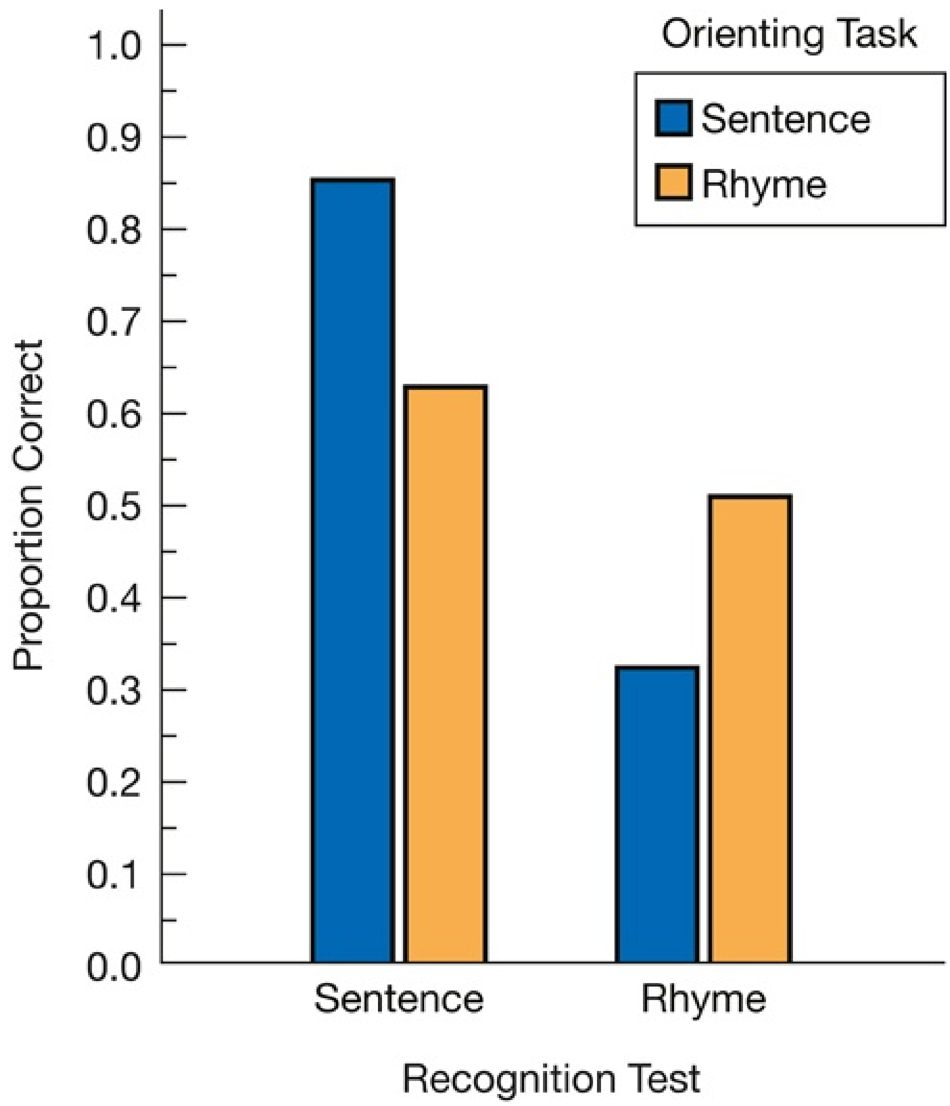

FIGURE 7.4 *Results of a Study of Transfer Appropriate Processing*

Adapted from: Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior*, *16*, 519–533

Stop and Review

Episodic memories store information about the context in which events were experienced. Context can refer to the external environment or people's physiological or emotional states. According to the encoding specificity principle, when the encoding and retrieval context match there is a greater likelihood of retrieving information later. However, when they differ, memory retrieval can be impaired. Finally, episodic memories also contain information about the mental processes used to create them, which can affect the transfer appropriate processing principle.

REPETITION AND PRACTICE

The more a person is exposed to information, the more likely it will be remembered. This is called a **repetition effect**. For example, information that is studied twice is more likely to be remembered than information studied only once. Having said that, repeated exposures vary in their effectiveness. How information is practiced can have a profound impact on memory.

Massed and Distributed Practice

Practice can affect memory depending on whether repeated exposures are grouped together or spread out over time. This is a distinction between massed and distributed practice. **Massed practice** is when there is a single, lengthy study period. For example, if a person decides to spend five hours studying, massed practice would be a single five-hour session. In contrast, **distributed practice** (also called spaced practice) occurs when the effort is spread out across multiple study periods. For example, a person studies for five hours by studying for one hour per day for five days. Massed practice is like cramming, and distributed practice is like consistently studying across a term. In general, memory is better following distributed practice than massed practice, and the longer the spacing between the distributed practices, the better memory is (Glenberg & Lehmann, 1980).

As an example of the difference between the consequences of massed and distributed practice is shown in Figure 7.5. As can be seen, memory improved at a greater rate for distributed practice compared to massed practice. Distributed practice improves memory, even years later (Bahrick, Bahrick, Bahrick, & Bahrick, 1993). What is odd is that people are largely unaware of the impact of different kinds of practice. Zechmeister and Shaughnessy (1980) found that students report that they think that memory is better after massed than distributed practice. This is the opposite of reality. There are a number of explanations for why this difference in practice types occurs. These are presented next.

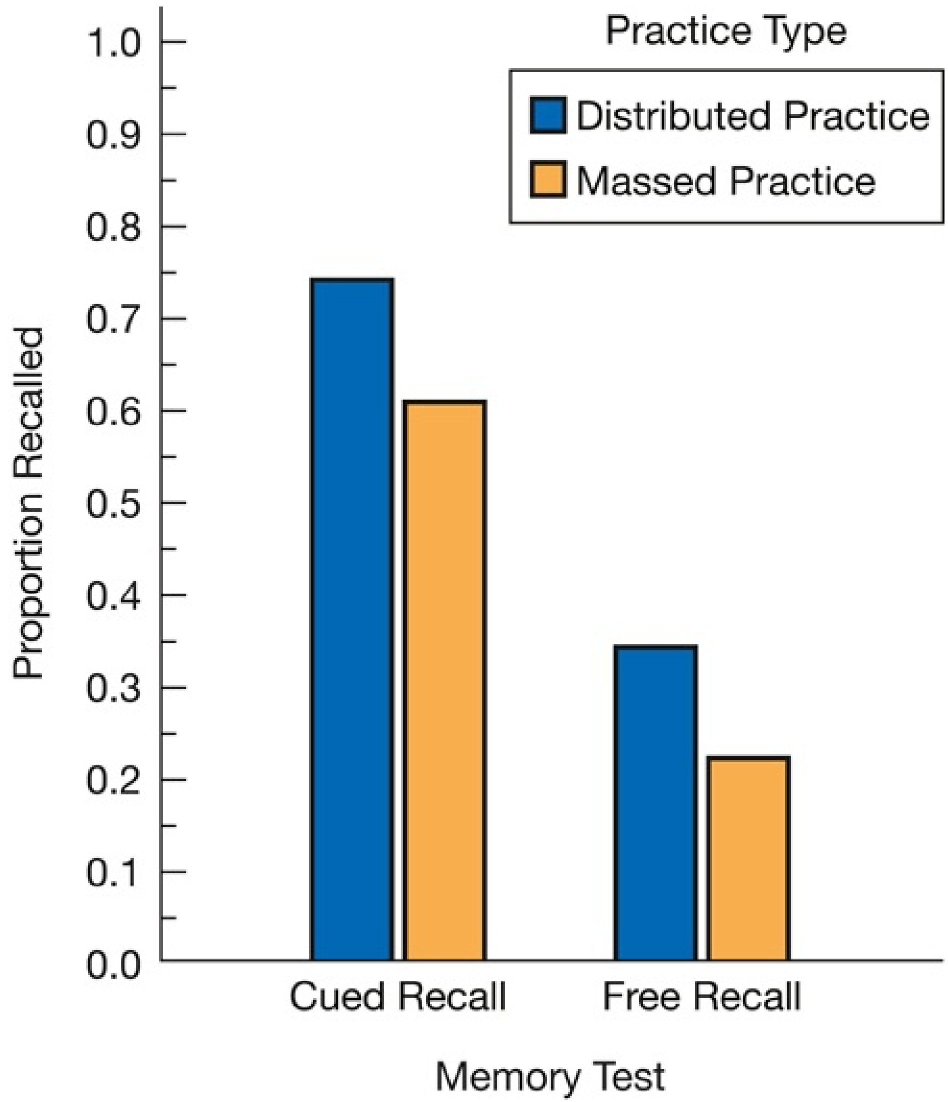

FIGURE 7.5 *Effects of Massed Versus Spaced Practice on Subsequent Memory (With a Constant Context)*

Adapted from: Glenberg, A. M. (1979). Component-levels theory of the effects of spacing of repetitions on recall and recognition. *Memory & Cognition*, *7*, 95–112

The first explanation is a **consolidation account**, in which massed practice is inferior because consolidation has not run its course. With distributed practice, there is more consolidation and so memory is better (Landauer, 1969;

Wickelgren, 1972). Moreover, the more a trace is consolidated, the less it is disrupted by other processes that may occur. Mass practice may overload the system, preventing some of the information from being consolidated. With distributed practice, the consolidated information is easier to build upon that later.

A second explanation is a **deficient processing account**, in which massed practice reflects a deficiency in processing. There are two ways that this might come about. One is a habituation/attention variant in which people habituate to information during massed practice and so do not as actively attend to it, leading to poorer memory (Hintzman, 1974). An accessibility/reconstruction variant is that massed practice is worse because less effort is needed to retrieve a memory because it is so fresh. As a result, people assume it is learned and do not devote the amount of time and effort needed to learn it.

A third explanation is a **contextual variability account**, in which differences in the variability of the contexts stored in the traces accounts for the differences in memory after massed and distributed practice (Glenberg, 1976, 1979). For massed practice, the contexts are roughly the same. However, for distributed practice, the contexts (both internal and external) of each session are more varied. A wider variety of contexts provides more retrieval pathways, and the more likely the information can be accessed when needed. Moreover, having an opportunity to sleep between study sessions results in better memory (Bell, Kawadri, Simone, & Wiseheart, 2014). With different days, there is a greater shift in context than if study sessions are separated within the same day, even if by 12 hours.

While the contextual variability account emphasizes differences between memories from different learning attempts (i.e., changes in context), a **study-phase retrieval account** emphasizes the similarities. When people have subsequent study sessions, this reminds them of prior sessions, allowing connections to be made between them (Benjamin & Tullis, 2010; Thios & D'Agostino, 1976). With distributed practice, this reactivates prior memory traces, thereby strengthening them and boosting resistance to later forgetting. Also, the more connections between the information, the more elaborate the memory traces and the better the information is remembered.

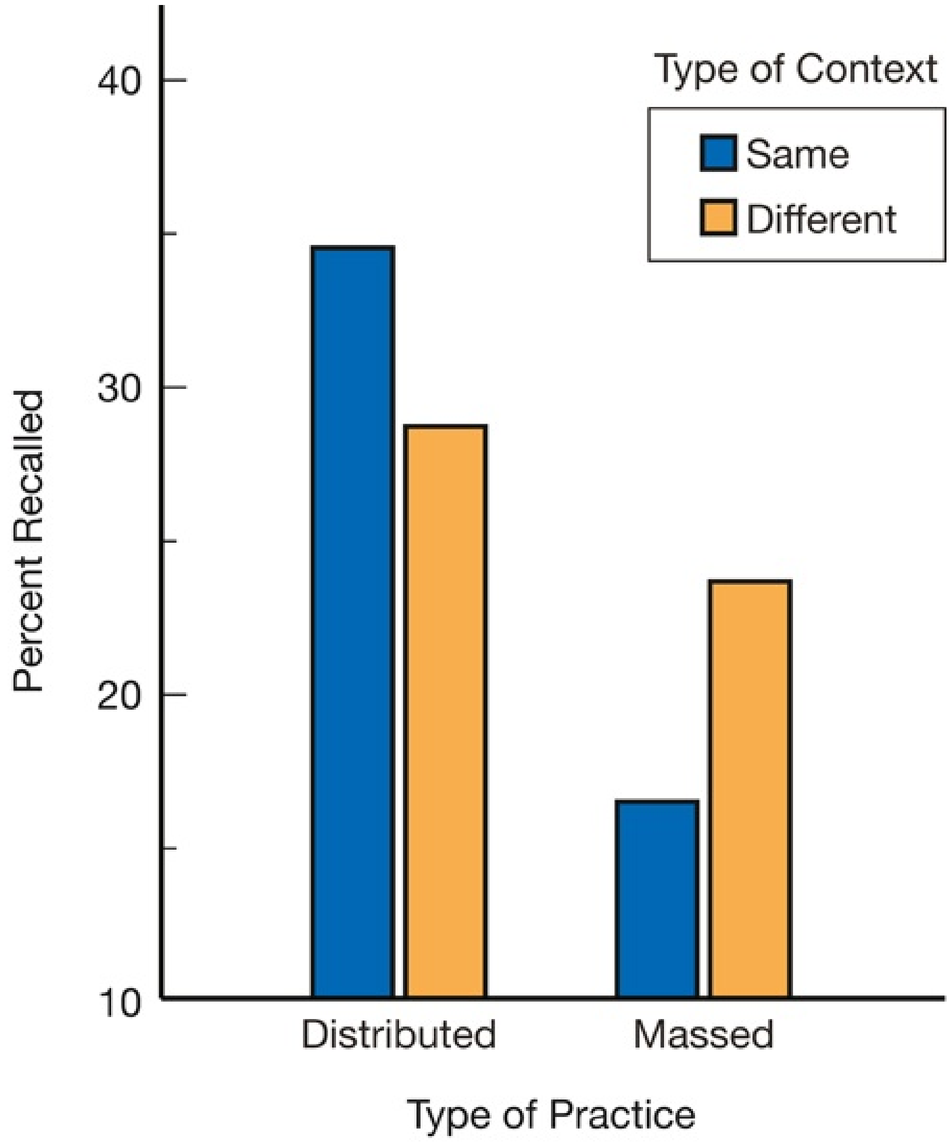

FIGURE 7.6 *Effects of Massed Versus Spaced Practice on Subsequent Memory (With Varying Context)*

Source: Verkoeijen, P. P. J. L., Rikers, R. M. J. P., & Schmidt, H. G. (2004). Detrimental influence of contextual change on spacing effects. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 30*, 796–800

An illustration of the interplay between context and practice is a study by Verkoeijen, Rikers, and Schmidt (2004). People were given either massed or distributed practice, with all the items shown on the same or a different background (context) each time. The results are shown in Figure 7.6. For massed practice, showing each item on a different background helped memory because, even though repetitions occurred close in time, each presentation was in a different context, thereby facilitating retrieval. In contrast, for distributed practice, the information was already distinct and so having each presentation of an item on a different background actually made things worse. Here, changing the context made it harder to remember previous study experiences, so memory was poorer. However, when the background was the same in distributed practice, this reminded a person of the previous experiences and facilitated memory.

Schedules of Practice

Another important issue to consider when thinking about memory and practice, and particularly how to do distributed practice, is the difference between uniform, expanding, and contracting **schedules of practice**. For a uniform schedule of practice, there is a consistent delay between study periods (e.g., study every seven days), whereas for an expanding schedule, there are increasing delays (e.g., one day, three days, six days, 12 days, etc.), and for a contracting schedule there are decreasing delays (e.g., seven days, six days, five days, four days, etc.).

Very few studies suggest that a contracting schedule produces better learning. For consistent delay and expanding schedules of practice, some studies have found no difference (Karpicke & Roediger, 2010), although both are better than massed practice. However, it has been noted that most of these studies manipulated the schedule of practice within a single session (Kang, Lindsey, Mozer, & Pashler, 2014). Other studies have found that expanding schedules produce a greater memory benefit (Gerbier & Koenig, 2012), which is consistent with the contextual variability account in that as the delays grow larger the contexts become more varied. It should also be noted that Lindsey, Shroyer, Pashler, and Mozer (2014) describe a method where faster learning can occur using individualized schedules of rehearsal.

Overlearning and Permastore

If a person continues to practice memorized information, then **overlearning** occurs (Driskell, Willis, & Copper, 1992). As reported by Ebbinghaus, overlearning strengthens memories and increases resistance to forgetting. Actors and musicians continue to rehearse their parts even after they are flawless to overlearn them. What about things that you learn in school? You are in college right now. What is the fate of the information you are learning? Is it subject to the forgetting curve? What is the point of learning if you're only going to forget it all later? Well, although there is an initial period of forgetting, a great deal of what is learned in school is retained throughout life.

Harry Bahrick, at Ohio Wesleyan University, has addressed these issues. His method is to get people attending college reunions and test their memories for their course material, such as Spanish, from three months to 50 years after graduation. He discovered that, although there is an initial period of forgetting for about three years, there is little forgetting after that (Bahrick, 1984). Similar effects have been found in actors' memories for play lines (Noice & Noice, 2002). These stabilized memories are described by Bahrick as being in **permastore**. Permastore can be thought of as the deep freeze of memory. Memories enter permastore following distributed practice and overlearning. The knowledge is so consolidated that it becomes very resistant to forgetting.

It is important to note that forgetting occurs at about the same rate for everyone. People who learn more forget at the same rate as people who learn less. Even after the initial forgetting period, the same differences in knowledge levels persist. The people who got A's always know more than the people who got C's (Bahrick, 1984; Conway, Cohen, & Stanhope, 1991). So, study hard.

To Study or To Test

Now, let's consider another way to practice, namely by taking a test. Intuitively, it seems that studying should lead to better memory than testing. After all, studying is what gets material into memory in the first place. However, the opposite is true. People typically learn more, after an initial study period, by taking a test rather than doing further study (Roediger & Karpicke, 2006). This is the **testing effect** (see Rowland, 2014, for a meta-analysis). The critical point here is not the test itself but the retrieval of the studied information. Thus, it is sometimes called the **retrieval practice effect** (Karpicke, 2012). One thing testing does is reduce the rate of forgetting. In a study by Roediger and Karpicke (2006), people who either studied further or took a test were assessed two minutes, two days, and one week later. The forgetting curves are shown in Figure 7.7. The forgetting curve is shallower for material that was tested compared with when it was only studied.[1]

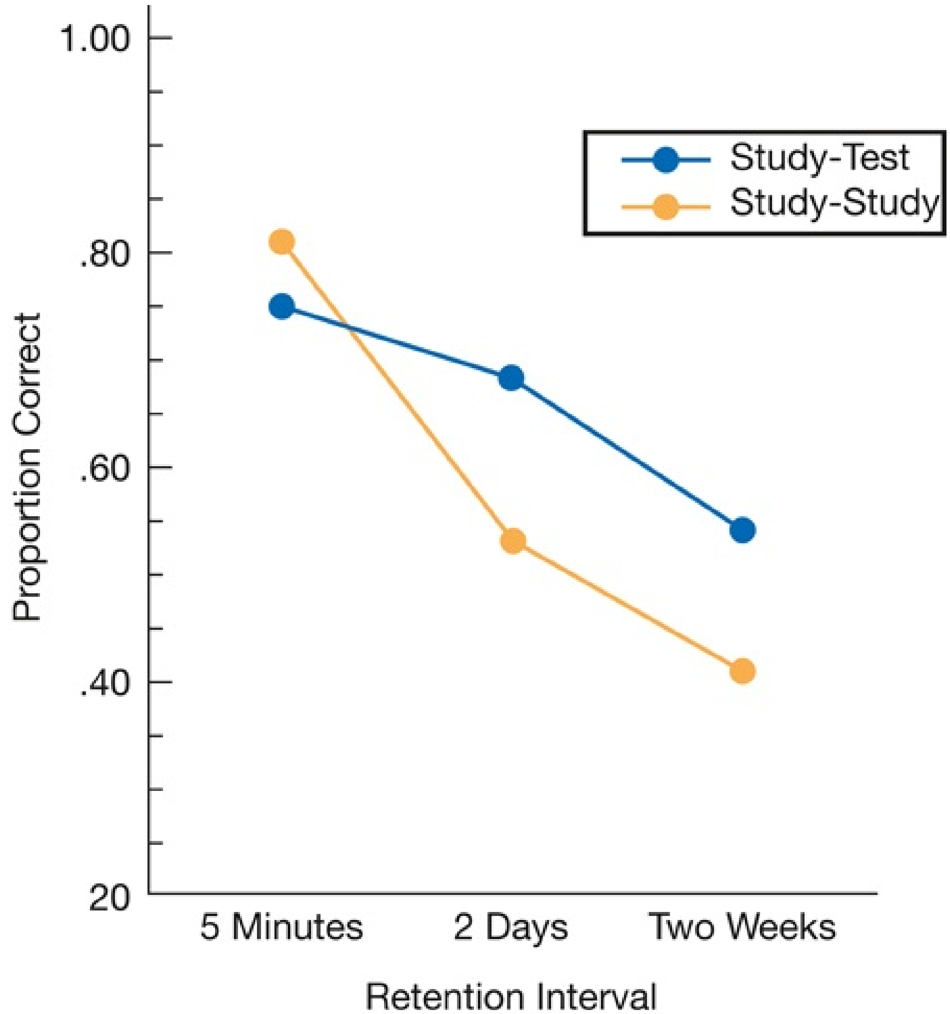

FIGURE 7.7 *Forgetting Curves as a Function of Whether People Simply Studied Material or Took a Test*

Adapted from: Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, *17(5)*, 249–255

The testing effect may occur because testing causes people to engage in deeper processing as part of the effort of taking the test (Carpenter, 2009). For example, testing increases the degree to which people organize information in memory, which boosts later retrieval (Zaromb & Roediger, 2010). In addition, the testing reduces effects of proactive interference (se Chapter 8) (Szpunar, McDermott, & Roediger, 2008).

Stop and Review

Memory is better with distributed than massed practice. Massed practice may (1) not allow consolidation to complete, (2) promote less effort, (3) have reduced contextual variability, and (4) provide fewer opportunities to link the knowledge with prior memories. With distributed practice, memory is better with expanding schedules of practice. Continued practice can cause overlearning and permastore storage. Finally, the testing effect demonstrates better memory when practice takes the form of a test rather than studying more.

Improving Your Memory

As you've read, memory is actually better if, after initially studying something, you take a test rather than continue to study more. You can use the testing effect to improve your own memory for things that you are learning in school. What you should do, on a regular basis, is meet with some of your classmates to sit around and test each other. One person should have either the notes or the textbook (or both) and come up with questions for the others to answer. Being able to answer those questions will improve your memory more over that period of time than simply studying more. So, bottom line, a good way to improve memory for the material you are learning in your classes is to take quizzes and tests in a study group. Moreover, the act of thinking of such test questions also boosts memory because of the generation effect (see Chapter 3). Further still, not only does testing improve memory for the information that was tested but it also aids any subsequent learning of new information that follows (Arnold & McDermott, 2013). This is a more effective use of your time. Be sure to take turns being the tester and the answerer. Because other classmates are not always available, find ways to test yourself. A simple way to do this is to make flashcards.

ORGANIZATION AND DISTINCTIVENESS

This section considered the improvements in memory that come from organization (linking memories together) and distinctiveness (separating memories apart). Some coverage is given to each of these, along with a consideration of why these seemingly opposite processes can both enhance memory.

Organization

Episodic memory improves if people use **organization**. Figure 7.8 shows data for a study across a number of study sessions when a set of words was presented in either an organized (i.e., based on categories) or random manner. Thus, the effects of chunking also work in long-term memory. An example of a pre-established structure that can aid memory is shown in Figure 7.9. Here, a hierarchical organization categorizes 18 words into groups of three or four items. Each of these sets is chunked and the chunks are chunked.

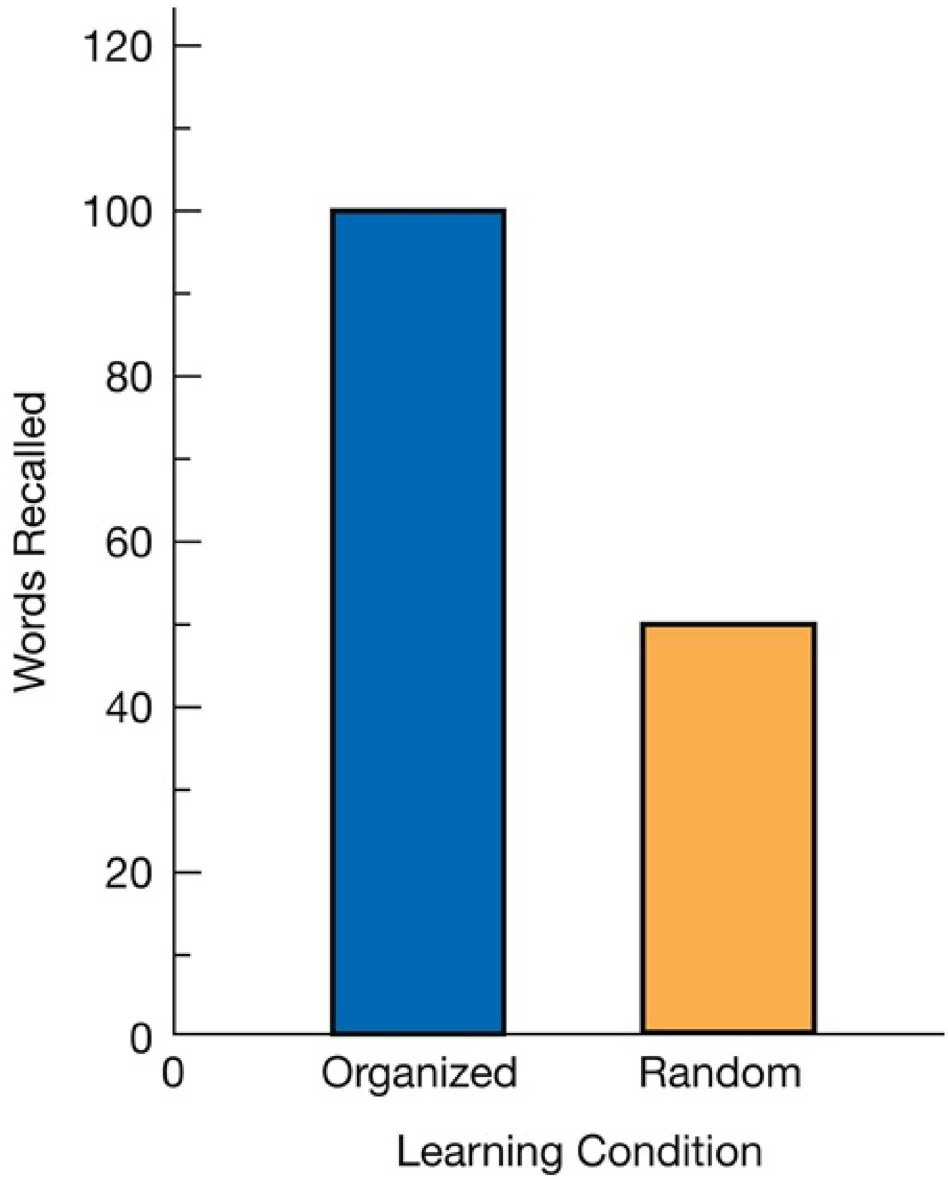

FIGURE 7.8 *The Influence of Studying Random Versus Organized Study Materials*

Adapted from: Bower, G. H., Clark, M. C., Lesgold, A. M., & Winzenz, D. (1969). Hierarchical retrieval schemes in recall of categorized word lists. *Journal of Verbal Learning and Verbal Behavior*, *8*, 323–343

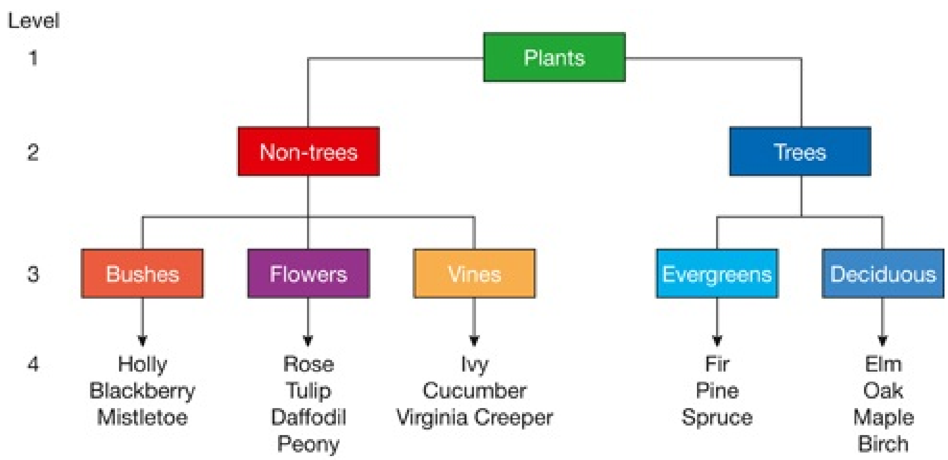

FIGURE 7.9 *Example of a Hierarchical Structure that Can Be Used to Help Organize Memory*

Adapted from: Bower, G. H., Clark, M. C., Lesgold, A. M., & Winzenz, D. (1969). Hierarchical retrieval schemes in recall of categorized word lists. *Journal of Verbal Learning and Verbal Behavior*, *8*, 323–343

The influence of organization and elaboration on memory is seen in actors' memories for scripts. Actors learn scripts amazingly fast if they were simply rote learning a series of sentences. However, they are doing much more than this. They organize the material not only based on the semantic information but also by creating integrated perceptually based images, self-referencing the information by taking the perspective of the character, generating the lines themselves, as well as the way they are to be delivered, and generating emotional states to match the mood of the character (Noice & Noice, 2006). All this serves to organize the material into a larger whole and allows it to be memorized relatively quickly.

Organization, and hence memory, can be enhanced when people either do something with the information or expect to do something with it. In a study by Nestojko, Bui, Kornell, and Bjork (2014), people were given passages to read with the expectation either that they would be tested for the content later or that they would teach the material to someone else. The expectation to teach led people to better structure and organize the information, which thereby boosted memory.

Distinctiveness

Episodic memory can be enhanced when a memory trace is separated out from competing ones that produce interference (see Chapter 8). Thus, memory is better for items that are distinct. For example, if one word is printed in red in a list of black words the word in red is remembered better. Similarly, if the word "tulip" appears in a list of vehicle names, the word "tulip" will be remembered better. This is called the **von Restorff effect**, after the woman who discovered it (Hunt, 1995). It is also called the **isolation effect** because the distinctive item can be isolated from its contrasting context. This effect is more likely to be observed with recall than recognition (van Dam, Peeck, Brinkerink, & Gorter, 1974). This may be because recognition does not require a comparison with any of the other surrounding information that would make up the context in which a distinctive item was present. It is the setting or context that often makes something distinctive, not just the thing itself. This is also one of the ideas for why emotional information is remembered better than neutral information (Talmi, Luk, McGarry, & Moscovitch, 2007). Emotional events are distinct against a background of more common events.

An example of distinctive processing is the **bizarre imagery** effect. Here, people form mental images of something they are trying to remember. The act of forming a mental image involves some work, so it improves memory (see Chapter 3). However, we can go a step further by creating bizarre images. For example, to remember to buy ice cream, tomatoes, and carrots at the grocery store, you might imagine a bowl of ice cream with a face made with slices of tomatoes and carrots. Overall, people remember more when they use bizarre imagery as compared to normal imagery (Einstein & McDaniel 1987). However, bizarre imagery only improves memory when a portion of the information gets this treatment. If more than half of everything is bizarre, none of the information is distinct and memory is not improved (McDaniel & Einstein, 1986). The bizarre imagery effect, like the more general isolation effect, reflects an influence on the ability to access the information at retrieval rather than different amounts of attention paid to information during learning (Riefer & Rouder, 1992).

Part of the impact of distinctive events on memory is that they are, in some way, unexpected. The occurrence of unexpected events results in increased neural processing, such as in the hippocampus and the nucleus accumbens (BA 34), which then enhance memory (Axmacher et al., 2010).

Relational and Item-Specific Processing

At this point there may seem to be a contradiction. On the one hand, organization helps memory, but, on the other hand, distinctiveness helps memory. These processes seem to be working in opposition. The more organized information is, the less distinctive the elements are, because similarities are emphasized. Conversely, the more distinct information is, the less organized it is, because differences are emphasized. It is clear that both of these processes are at work (Hunt & Einstein, 1981; Hunt & McDaniel, 1993). **Relational processing** is helpful in generating a retrieval plan for later recall. **Item-specific processing** helps reduce sources of interference. Each of these has an impact on memory (Einstein & Hunt, 1980). The degree to which each of these aids memory is a function of the current set of information.

An illustration of the differential effects of relational and item-specific processing is a study by Hunt and Seta (1984). In this study, people learned items from categories of different sizes. They learned by emphasizing either relational processing (sorting items into categories) or distinctive, item-specific processing (rating items for pleasantness). The results, shown in Figure 7.10, illustrate that memory was better for small categories when relational processing was emphasized (helping identify the interrelations among the few members of a category) but was better for larger categories when distinctiveness processing was emphasized (helping people contend with larger amounts of interference).

Another explanation for of distinctiveness effects in mixed lists (common and unusual items), but not pure lists (all unusual items), is based on memories for item-order information (the sequence information was learned in). According to McDaniel and Bugg (2008), people remember distinctive information in mixed lists better because unusual items encourage item-specific processing. This takes away the opportunity to do relational processing for encoding the order in which information occurs (how one piece of information relates to another in the sequence in which it was encountered). As such, when this is disrupted in mixed lists people show relatively better memory for the unusual items, but in pure lists, order information is uniformly disrupted, and performance on the unusual items does not stand out.

The distinction between item-specific and relational processing has implications for learning. Memory is better if the type of learning emphasizes the information for which memory is likely to be weak. This is the idea behind **material appropriate processing** (Einstein, McDaniel, Owen, & Cote, 1990). For example, with descriptive texts, such as a college textbook, the emphasis is on sets of facts, or item-specific information. As such, memory is better if people engage in learning that emphasizes relational information. In contrast, with narrative texts, such as a novel, the emphasis is on the narrative flow and the interrelations among the events or relational information. As a consequence, memory is better in this case if people engage in learning that emphasizes item-specific information.

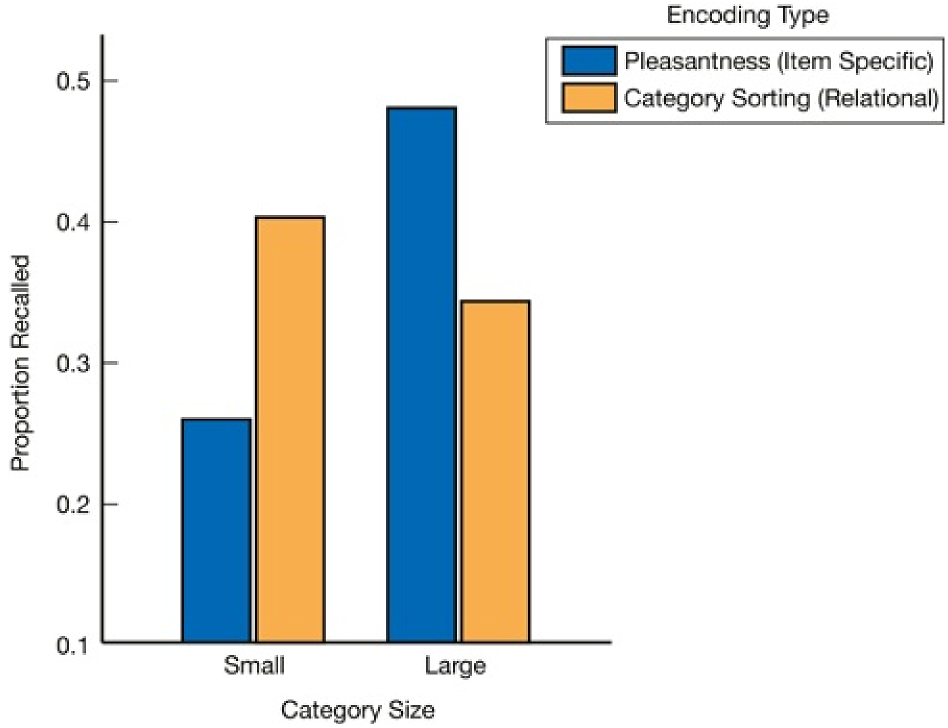

FIGURE 7.10 *Effects of Learning Emphasizing Distinctiveness and Relational Processing as a Function of Category Size*

Adapted from: Hunt, R. R., & Seta, C. E. (1984). Category size effects in recall: The roles of relational and individual item information. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 10*, 454–464

PHOTO 7.2 *According to the adaptive memory perspective, memory is better for information that is related to our survival; this builds on theories that memory evolved to remember those things that were more critical to survival in various environments, such as the African savannah*

Source: czekma13/iStock/Thinkstock

Adaptive Memory

There are a number of things that can influence later memory. One area of research that has been exploding has been looking at the influence of evolutionary pressures on the effectiveness of memory (Nairne & Pandeirada, 2008). The basic idea driving this work is that our memories did not develop in a vacuum but evolved to serve particular environmental problems, perhaps those related to survival on the African savannah during the Pleistocene. Evolutionary pressures in this setting pushed us to be able to remember some things better than others.

It has been found that people respond faster to words based on their subjective level of danger or usefulness (Wurm, 2007). Presumably, the more dangerous or useful something is, the more likely it will be helpful to know about. Remembering this type of information is helpful to survival. Another important aspect of survival is knowing which places are dangerous and which are not. Thinking about the survival value of items helps one remember the locations where they were encountered (Nairne, VanArsdall, Pandeirada, & Blunt, 2012). This bias for survival related information may also play into the fact that animate concepts (e.g., deer, dog, bird) are better remembered than inanimate ones (e.g., cloud, chair, ball). Animate entities are more likely to have implications for survival than inanimate ones (Nairne, VanArsdall, Pandeirada, Cogdill, & LeBreton, 2013).

STUDY IN DEPTH

The idea that memory has evolved to accommodate environmental pressures is having a profound influence on research. A seminal study that started this effort was done by Nairne and Pandeirada (2008). In one of their experiments, they tested 32 students from Purdue University. They had people go through a series of word lists from four categories: four-footed animals, weather phenomena, vegetables, and types of human dwellings. There were eight words for each category. The words from a given category were presented together, although the order of the words with a given category was randomized.

The important manipulation was whether a given word was rated for (1) pleasantness (e.g., “How PLEASANT is this word?”), or survival (e.g., “How relevant is this word to the SURVIVAL situation?”) on a 1 to 5 scale, with 1 indicating totally unpleasant/irrelevant and 5 indicating extremely pleasant/relevant. The instructions for the pleasantness ratings were:

> In this task, we are going to show you a list of words, and we would like you to rate the pleasantness of each word. Some of the words may be pleasant and others may not—it’s up to you to decide.

In comparison, the instructions for the survival situation were:

> In this task we would like you to imagine that you are stranded in the grasslands of a foreign land, without any basic survival materials. Over the next few months, you’ll need to find steady supplies of food and water and protect yourself from predators. We are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in this survival situation. Some of the words may be relevant and others may not—it’s up to you to decide.

The actual ratings that the people provided are not of concern here. Each word was presented for five seconds in the center of a computer screen and the response needed to be given within that time. People were given a short practice period with four additional words to familiarize themselves with the task.

After rating all 32 words, people were given a short distractor task of remembering sequences of seven digits in order (a standard digit span task). This was done for two minutes. Following this, people were given a surprise memory task in which they were asked to recall as many of the words they had seen during the rating period as they could. What was found was that people remembered the words rated for survival relevance to a greater degree (66%) than those rated for pleasantness (55%). The explanation is that memory is more attuned to matters relating to personal survival.

Having people focus on survival value provides some of the best memory performance compared to other ways of boosting memory, including creating mental images, generating information, and intentional learning (Nairne, Pandeirada, & Thompson, 2008), and persists over long periods of time, such as a day or two later (Raymaekers, Otgaar, & Smeets, 2014). Memory seems more attuned to grass-lands survival than city survival (Weinstein, Bugg, & Roediger, 2008), which is consistent with an evolutionary perspective. The survival effect is observed so long as there is a perceived threat (Olds, Lanska, & Westerman, 2014). For example, this survival benefit is observed when the threats are zombies (which are imaginary) (Soderstrom & McCabe, 2011). This occurs because, even though zombies were not present in the African savannah during the Pleistocene, they would still be predators and so would be a threat to survival.

Relatedly, just thinking about one's own death, such as being on death row, can produce a survival memory benefit (Burns, Hart, & Kramer, 2014; Hart & Burns, 2012). While thoughts of death improve memory, these benefits do not seem to be as great as those associated with a more general survival-based thinking (Klein, 2014).

So, why do people have better memory for things that they think about in terms of their own survival? Some of this is a benefit from processes that are already known to boost memory, such as elaborative processing (Kroneisen & Erdfelder, 2011), increased item-specific and relational processing, relating information to one's self, and distinctive processing (Burns, Burns, & Hwang, 2011; Klein, 2012). Moreover, a compelling argument has also been made that when people are thinking about their own survival they think more about the usefulness of the items or information (Bell, Röer, & Buchner, 2015), and are engaging in more planning of what they will do to survive (Klein, Robertson, & Delton, 2011).

Stop and Review

Memory is improved by putting information into an organizational structure. Episodic memory is also improved by making new information distinct. While these two seem to be at odds, both are effective in the right circumstances. Relational processing improves memory for information for which it is unclear how it relates to what is already known. Conversely, item-specific processing improves memory when people already have a well-developed organization, thereby helping make knowledge stand out and be less affected by interference. Recent work suggests that thinking about information within an adaptive, survival context can boost memory.

MEMORY FOR THE FUTURE

As mentioned at the beginning of the chapter, one of the hallmarks of episodic memory is mental time travel. Up to now we have been talking about travel backward in time. That is, episodic memory processes in service of remembering what had happened. In this section we consider mental time travel into the future, that is, episodic memory processes in service of what will happen. The primary reason we have the memories is not so that we can think about the past but so that we can think about what we will do in the future (Klein, 2013a). After all, survival is more likely for creatures that have some degree of expectation, prediction, and planning ability. There are two types of memory for the future considered here. The first is remembering to do something in the future, which is prospective memory. The other is the ability to imaging how events will unfold in the future, which is episodic future thinking.

Prospective Memory

Prospective memory is remembering to do things in the future (Loftus, 1971). Remembering to give your roommate a message or take the pizza out of the oven in 20 minutes are both examples of prospective memory. The (un)successful operation of prospective memory plays a critical role in the adherence of patients to their medication schedules (Zogg, Woods, Sauceda, Wiebe, & Simoni, 2012). Prospective memory can even be conceived as remembering to not do something that is normally done (Pink & Dodson, 2013), such as remembering not to back the car out of the garage after new cement has just been put down for the driveway. This is in contrast to retrospective memory, or memory for the past, which is the focus of much of this book.

Prospective memory has been tested in a number of ways. Some of these are naturalistic, such as having people remember to call at certain times (West, 1988). Others are laboratory-based, such as having people press a button when they see a certain word (Einstein & McDaniel, 1990) or after a certain amount of time has elapsed. Some studies have struck a middle ground and use virtual environ ments (Trawley, Law, & Logie, 2011). In general, the more important a prospective memory task is viewed as being, the more likely it is to be done (Walter & Meier, 2014).

There are many differences between prospective and retrospective memory. In general, prospective memory has some unique components that are not found in retrospective memory. Prospective memory involves: (1) monitoring the environment for the cue to do something, (2) remembering what to do in the future, (3) retrieving the memory of what to do, and (4) actually doing it. Number 2 is similar to what is involved in retrospective memory. Thus, prospective memory depends on retrospective memory ability but not vice versa. The other parts are unique to prospective memory. They involve the deliberate monitoring of the environment for a cue to remember, as well as the imagining of what will be done, a form of episodic future thinking (see next section) (Terrett et al., 2016). This is absent in retrospective memory.

Prospective memory requires control of thought, a frontal lobe function, which involves conscious experience to a greater degree. As a consequence, people are more aware of their prospective than their retrospective memory errors. People who complain about memory problems are more likely to have prospective memory problems (Mäntylä, 2003). Prospective memory also requires a constant monitoring of the environment. This comes at a cost as people have fewer memory resources for other tasks, especially if they have a relatively large number of things that they need to remember to do (Hicks, Marsh, & Cook, 2005). So, when you have a lot to do, you are more likely to make a prospective memory error and forget to do something that you were supposed to do.

There are two types of prospective memory: event-based and time-based (Einstein & McDaniel, 1990). **Event-based prospective memory** is when people need to remember to do something when some event occurs—for example, remembering to give a person a message when you see him or her. Event-based prospective memory can be influenced by the relation between the event that is supposed to signal you to remember and the action that is to be done (McDaniel, Guynn, Einstein, & Breneiser, 2004). When they are semantically associated (e.g., write down the word "needle" when you hear the word "thread"), prospective memory is more automatic and is less influenced by things like divided attention. However, if the event and action are not associated (e.g., write down the word "needle" when you hear the word "parasol"), prospective memory is more deliberative and can be more easily disrupted if attention is drawn elsewhere.

Event-based prospective memory also is more difficult when there are multiple cues as opposed to one, and even more difficult if those cues are unrelated to one another (Marsh, Hicks, Cook, Hansen, & Pallos, 2003). In essence, attention is drawn away from the prospective memory task when it is divided up among different things in the environment that one needs to watch out for.

Time-based prospective memory is when people need to remember to do something at a certain time or after a certain time interval. Remembering to call home on Mother's Day or to take another pill in four hours are examples of time-based prospective memory. Time-based prospective memory is harder than event-based prospective memory (Einstein et al., 1995). With event-based prospective memory, there is something in the environment that reminds you what needs to be done. With time-based prospective memory, it is up to the person alone to remember. We can improve our time-based prospective memory by making it more event-based. For example, you could set a timer and just wait for the buzzer to go off (an event) to remind you to take your pill.

With time-based prospective memory, people make more errors if the tasks are repetitive—for example, taking medications after certain intervals. The more people have done the task, the more likely an error will be made and they will forget. Part of what is going on is that source monitoring errors occur (see Chapter 13), which then cause problems with prospective memory (Einstein, McDaniel, Smith, & Shaw, 1998). For example, people may be confused and think that they had just taken medication, when in fact they are remembering another time that they did so. This is a case in which doing something frequently actually makes memory worse, not better.

A third type of prospective memory that is not as well researched is **activity-based prospective memory**. Here, people are asked to do something after another task has completed (e.g., Kumar, Nizamie, & Jahan, 2008). For example, people might be asked to call their doctor after they are done watching a television show. Thus, prospective memory can guide a sequence of actions.

Another prospective memory issue is the relation between the prospective memory task and the ongoing task in which it is embedded, particularly for event-based prospective memory. That is, whether the prospective memory task is focal or nonfocal (McDaniel & Einstein, 2011). A prospective memory task is **focal** when it is part of the ongoing task. For example, suppose you are given a task in which you see a list of animal names and you are to classify them as to whether you would display them in a zoo (e.g., you would respond "yes" to "penguin" and "no" to "squirrel"). For the prospective memory task, you might be asked to press the space bar if you see the word "lion." This is focal because attention is already directed to the prospective memory cue as part of the ongoing task.

In comparison, a prospective memory task is **nonfocal** when it is not part of the ongoing task. For example, suppose during the animal classification task, instead of monitoring for the word "lion," the task is to press the space bar whenever a small box in the upper left-hand corner of the screen flashed three times. When attention is divided, as it is with a nonfocal task, prospective memory is worse, suggesting that some element of cognitive control is needed (Harrison, Mullet, Whiffen, Ousterhout, & Einstein, 2014).

The distinction between focal and nonfocal tasks maps onto different neurological processes, as revealed by fMRI and MEG studies. On the one hand, focal tasks involve more working memory processes and so are more likely to involve processing operating in the medial temporal lobe (McDaniel & Einstein, 2011) or posterior parietal lobe (Martin et al., 2007). In comparison, nonfocal tasks rely on more frontal lobe processes (Cockburn, 1995; Simons, Schölvinck, Gilbert, Frith, & Burgess, 2006). This is because people need to disengage from the current task and attend to something else to do the prospective memory task.

Episodic Future Thinking

Another way that episodic memory is involved in the future is when people imagine or plan for what may happen in the future. For example, thinking about how you will spend your afternoon today, how will you get that special someone to notice you, or what will happen if you drive in today's heavy snowfall. This is **episodic future thinking** (Atance & O'Neill, 2001; Szpunar, 2010; Szpunar & Radvansky, 2016) or **future-oriented mental time travel** (Klein, 2013b, 2016). Episodic future thinking allows us to better predict and prepare for the future through adequate planning of how things may unfold in time (Klein, Robertson, & Delton, 2010). This is something that we do quite often. D'Argembeau, Renaud, and Van der Linden (2011) estimated that it is something we do every 15 minutes or so.

Although this is not "memory" per se, episodic future thinking uses many of the same neurological components as episodic retrospective memory (Addis & Schacter, 2008), including left hippocampus processing and posterior visual processing (Addis, Wong, & Schacter, 2007; Szpunar, Watson, & McDermott, 2007). The retention and projection of episodic memories and future thoughts follow similar gradients, such as the idealized patterns shown in Figure 7.11. The distance into the past or the future engages the left posterior hippocampus (which is involved in contextual aspects of episodic memory) to similar degrees, regardless of the direction of time (Addis & Schacter, 2008; Spreng & Levine, 2006).

When we think about the future, we use our prior episodic memories of similar experiences to guide what we imagine what the future will be like (Szpunar & McDermott, 2008). This is the **constructive episodic simulation hypothesis** (Schacter & Addis, 2007). This is a form of mental time travel because it feels as though one is pre-experiencing future events in much the same way that it feels like one is re-experiencing events from the past (D'Argembeau & Van der Linden, 2004; McLelland, Devitt, Schacter, & Addis, 2015). The more thoughts of the future conform to our episodic experiences, the easier they are to construct (Szpunar & Schacter, 2013; van Mulukom, Schacter, Corballis, & Addis, 2016). For example, it is easier to imagine a future event involving yourself and two friends from school (because you are likely to have had experiences with them together in the past) than to imagine a future event involving yourself, a friend from school, and a friend from work (because these are different social circles and so are likely to involve different events).

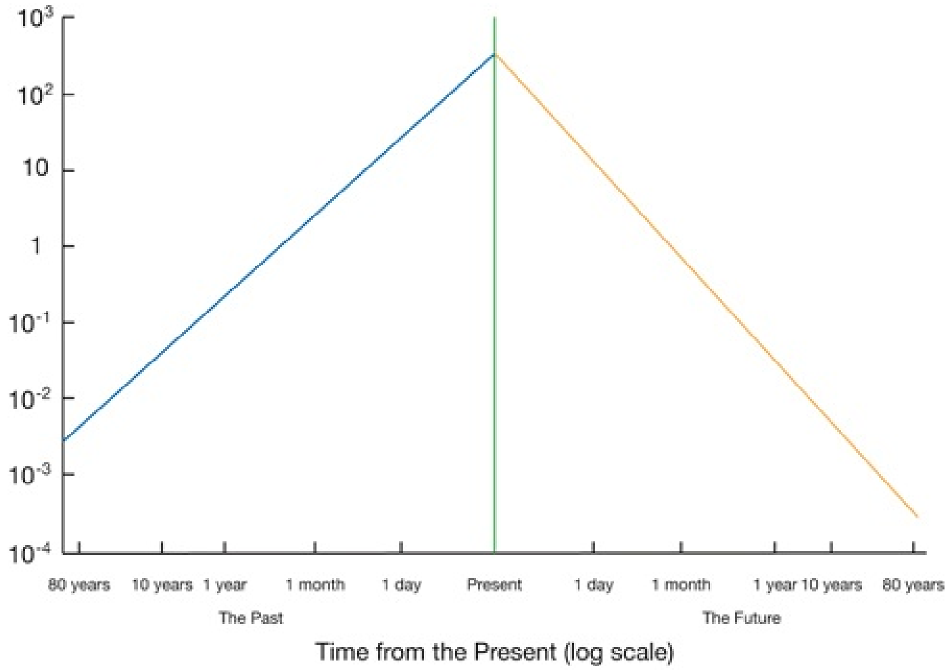

FIGURE 7.11 *Idealize Functions Episodic Past and Future Thinking, Showing that the Pattern of Event Memories Reported is Roughly Symmetrical for Various Distances from the Present*

Adapted from: Spreng, R. N., & Levine, B. (2006). The temporal distribution of past and future autobiographical events across the lifespan. *Memory & Cognition*, *34*(8), 1644–1651

That said, there are also differences in processing past and future events. In general, episodic future thinking is more difficult than remembering past events, is less vivid, more positive, and more important for the life story (people tend to think about the future in terms of how they would like their life to unfold) (Anderson, Dewhurst, & Nash, 2012; Berntsen & Bohn, 2010; Grysman, Prabhakar, Anglin, & Hudson, 2015; Rasmussen & Berntsen, 2013). Neurologically, the anterior hippocampus, the right frontopolar cortex (BA 10), and the left ventromedial pre frontal cortex (BAs 14, 25, and 32) are more engaged for future events, perhaps related to planning (Addis et al., 2007; Okuda et al., 2003). There is also some evidence that the left precuneus in the parietal lobe (BA 7) and parts of the right cerebellum are more active during episodic future thinking (Szpunar et al., 2007).

Stop and Review

Episodic memory is important for thinking about events of the future. Prospective memory is remembering to do something in the future. This can be event-based, time-based, or activity-based. Each has its own demands and challenges. Moreover, the ease with which a prospective memory task is done is a consequence of whether it is focal or nonfocal. Another future-oriented use of episodic memory is episodic future thinking. This draws on episodic memories of the past as a guide to thinking about the future, as well as similar neurological structures. That said, there are differences, with episodic future thoughts being harder to create and also being more positive and central to the life narrative.

PUTTING IT ALL TOGETHER

Episodic memory is your mind's time travel device. Much of this is done with the integrative and binding abilities of the hippocampus. Using your episodic memories you can revisit previous experiences and events. You can also use it to plan and prepare for the future. You do this by integrating and interleaving information about yourself and what you do with information about what is going on in the environment. Within you are the thought processes, emotions, and bodily states that serve as contexts that are bound with memory, which also serve as a retrieval cues. These include transfer appropriate processing, mood-dependent, and state-dependent memory. What you do with the information is practice it. Different ways of bringing the material back into your current stream of thought has big impact later. How well practice improves memory reflects whether you practice the material all at once (bad) or spread it out (good), whether you spread out your practice using a fixed or an expanding schedule, whether you continue to study or take a test, and whether you think about how it relates to your survival. With the right kind of practice you can overlearn the information, consolidate it into your permastore, and retain for years on end. Finally, episodic memories of your life experiences give you the bases for thinking about what will happen in the future.

Outside of yourself, you remember the surface form, verbatim details, and the gist and holistic form of the mental models of the referred to events. Knowledge of the environmental gets into your memories and plays an important role in the ability to readily remember later, as evidence by the encoding specificity phenomenon. This is as true as for the spatial-temporal framework of your experiences as it is for the cuing elements that make it up, such as the sights, sounds, and smells. After these bits and pieces of content and context become part of your memories, they can then be used to cue yourself about what happened before. When learning, you improve your memory by emphasizing what is distinct about the material, as well as linking and organizing it with other things. Which of these is better at any given time depends on what is lacking in the material itself. Finally, in terms of the future, episodic memory is important for planning how to interact with the world at appropriate times, as with the various forms of prospective memory.

STUDY QUESTIONS

1. What is meant by the concept of mental time travel and why is this important for episodic memory?
2. What is the influence of serial order of event types on episodic memory?
3. What are the kinds of knowledge that are stored in episodic memories?
4. What kind of information can be used to cue episodic memory? Are some types of cue better than others?
5. How does context influence episodic memory? What are the different types of contexts?
6. What does transfer appropriate processing tell us about what information is stored in episodic memory and how it is remembered later?
7. What are the different types of practice that a person can engage in? Which of these is better for later memory retrieval?
8. What are the different explanations for why distributed practice is better than massed practice?
9. What are the different schedules of distributed practice and which of these seems to serve as a better aid to memory over long periods of time?
10. What is overlearning, how does it come about, and what are the consequences for long-term memory?
11. What is the testing effect?
12. How does organization help episodic memory? How does distinctiveness help episodic memory? How are they opposites? How can this puzzle be resolved?
13. How does the distinction between item-specific and relational information

influence later episodic memory?

14. What is adaptive memory and how does it relate to concept of evolution?

15. What is prospective memory? How does it compare to retrospective memory?

16. What are the different types of prospective memory? How is prospective memory affected by retention intervals?

17. What is episodic future thinking? How does this relate to episodic retroactive thinking?

KEY TERMS

- activity-based prospective memory
- bizarre imagery
- consolidation account
- constructive episodic simulation hypothesis
- contextual and encoding variability account
- cuing
- deficient processing account
- distributed practice
- encoding specificity
- episodic future thinking
- episodic memory
- event-based prospective memory
- focal
- future-oriented mental time travel
- isolation effect
- item-specific processing
- massed practice
- material appropriate processing
- mental time travel
- mood-congruent memory
- mood-dependent memory
- nonfocal
- organization
- overlearning
- permastore

- relational processing
- repetition effect
- retrospective memory
- schedules of practice
- self-reference effect
- semantic memory
- state-dependent memory
- study-phase retrieval account
- testing effect
- time-based prospective memory
- transfer appropriate processing
- von Restorff effect

EXPLORE MORE

Here are some additional readings to allow you to explore issues involving episodic memory more deeply.

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NOTE

1 See Bäuml, Holteman and Abel (2014) and Racsmány, Conway, and Demeter (2010) for evidence that the testing effect can sometimes be eliminated by sleep.

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CHAPTER 8

Forgetting

When our memories are working well and we can retrieve the information we need, we don't typically notice it. However, when our memories fail us and we forget things we are much more aware of our memories and our limitations. In general, when people take an interest in memory the focus is not on remembering but on the failure to remember, namely **forgetting**, and how to avoid it. The type of forgetting that is of concern here is the normal, standard, everyday kind of forgetting that we experience in our lives. When the loss of information in memory exceeds this expected amount, it is no longer normal forgetting and it crosses over into the catastrophic memory loss that is amnesia, which is the topic of Chapter 18. Often that kind of forgetting is due to some sort of trauma. Normal forgetting is not due to something going wrong with the mind or brain but instead is a consequence of the normal operation of memory and how it manages information.

In our consideration of forgetting, and the idea that forgetting is something bad, we first begin with Schacter's seven sins of memory, along with a consideration of why these sins may actually be virtues. This is followed by coverage of the viability of decay, or the passage of time, as a mechanism of forgetting. After that, we consider one of the primary mechanisms of forgetting, namely interference. This is followed by a discussion of the operation of inhibition, which is used to regulate the influence of interference. After this we consider when people deliberately seek to forget information with directed forgetting, and the management of knowledge that has been explicitly retracted. After that, we consider two aspects of experience that can influence the rate of forgetting, namely the collaborative forgetting that can occur when you try to remember things along with other people, and the influence of drugs and alcohol on forgetting.

THE SEVEN SINS OF MEMORY

In his book *The Seven Sins of Memory*, Schacter (2001) laid out an organization of memory problems as if they were seven sins. His **seven sins of memory** are: (1) transience, (2) absent-mindedness, (3) blocking, (4) misattribution, (5) suggestibility, (6) bias, and (7) persistence. An overview of each of these is presented here, followed by reasons why these seven sins may be virtues. You may want to keep these in mind when you consider both parts of this chapter, along with other parts of this book, when thinking about remembering and forgetting more generally.

Transience

The first sin of memory is **transience**, which is the idea that memories are forgotten with the passage of time. This is reflected in the forgetting curve of Ebbinghaus (1885/1964), discussed in Chapter 3. As a reminder, the more time that passes, the more likely that information will be forgotten, with forgetting being more rapid early on and then slowing down as time progresses. Keep in mind that not all aspects of a given memory are necessarily forgotten at once. As such, memories may still be present but become fragmented. The gaps in these memory fragments may be filled in with our general knowledge (see Chapter 9). Thus, memory can go from being **reproductive**, in which the prior knowledge is brought back into working memory, to being **reconstructive**, in which people fill in the gaps that are created by forgetting.

Absent-Mindedness

The second sin of memory is **absent-mindedness**, the idea that people are not paying attention when information is first encountered (and so it is never encoded into memory). As an example of this, Henkel (2014) had students at Fairfield University visit a museum. While there, they just looked at some objects and took photographs of others. What she found was that when people took photographs they remembered less than when they simply looked at the object. This occurred because the act of taking a picture takes one's attention away from what is going on in the environment and so people remember it less well.

Alternatively, absent-mindedness could occur if information makes it into memory but people somehow fail to retrieve it. This reflects the distinction between availability and accessibility. **Availability** is whether a trace is present somewhere in memory. It may not be available either because it was never encoded or because it has been permanently lost. In comparison, **accessibility** is the idea that the trace is somewhere in memory but the issue is whether people can successfully get to it or not. Sometimes forgetting reflects when a memory is available, but not accessible. Failure of accessibility can sometimes be overcome, as with cuing or with the phenomena of reminiscence and hypermnesia, discussed in Chapter 3, in which previously forgotten information is remembered later. These memories were available but not accessible until later.

Another issue that absent-mindedness is relevant to is how having attention divided among multiple tasks influences later memory. Divided attention during learning clearly disrupts encoding, so we won't go too much into that here.[1] Of more interest is whether dividing attention during retrieval can disrupt performance (Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Rohrer & Pashler, 2003). Distraction during retrieval can slow the rate at which information is remembered but overall accuracy is less affected, if at all. That said, divided attention can disrupt memory retrieval when the distracting task uses the same cognitive/neural systems (Fernandes & Moscovitch, 2000), for example if you were trying to recall a list of words while at the same time listening to another series of words to assess whether any were repeated three times in a row. There may actually be some benefits for divided attention during retrieval. Kessler et al. (2014) found that dividing attention at retrieval can boost later memory, particularly if there is at least a 24-hour delay between learning and the first memory test. The effort needed to compensate for the retrieval difficulty experienced on the first test boosts the memory trace, making it better retained and remembered later.

Blocking

The third sin of memory is **blocking**, the idea that people have trouble accessing a desired memory because other memories get in the way. That is, these other memories block the access to the desired one. For example, you may be trying to think of a person's name but other, similar names keep popping up in your mind. This is the sin of memory that gets the most attention in this chapter when we discuss interference and inhibition. An idea that fits well with the blocking principle is the concept of **cue overload**, in which the more things that are associated with a memory cue (i.e., the more memory traces that share that element), the less effective that cue will be. The more memory traces associated with a cue, the more these other traces interfere with or block access to the desired memory. This harkens back to the idea discussed in Chapter 7 that the best memory cues are the ones that are most diagnostic. Diagnostic cues have low cue overload.

Misattribution

The fourth sin of memory is **misattribution**, which is the idea that people can remember something but misattribute where it came from. This is a forgetting of the nature of a memory, not the content of the memory itself. For example, you may mistakenly remember something about President Lincoln from a textbook you read, when in fact it was in a fictional movie that you saw. Misattribution can be a striking occurrence, such as a feeling of déjà vu, or a more mundane experience of simply thinking that you remember information coming from one source when in fact it came from somewhere else. Issues of source monitoring are covered in detail in the Chapter 13. Moreover, Chapter 14 covers how misattribution can influence legal issues.

Suggestibility

The fifth sin of memory is **suggestibility**, in which memories can be implanted from outside sources, possibly causing correct information to be forgotten. This incorrect information may be introduced either explicitly or implicitly and may be done intentionally or unintentionally. Regardless of the circumstances, incorrect knowledge disrupts the functioning of memory. Issues of suggestibility are discussed in Chapter 13, where issues of memory and reality are brought into focus, as well as Chapter 14 in terms of incorrect information being suggested to witnesses.

Bias

The sixth sin of memory is **bias**, which is the idea that memory can be distorted toward what is already known. Thus, there is a forgetting of events or knowledge of one's prior mental states, as a function of what is currently known. This was briefly covered in Chapter 3's discussion of the hindsight bias, and these memory biases are discussed in more detail in Chapter 15.

Persistence

The seventh sin of memory is **persistence**, in which memory is compromised by incorrect knowledge that should be forgotten but it is not. So, a failure to forget can be a memory problem. This incorrect information continues to infiltrate our stream of thought and distort memory, decision-making, and thinking in general. The avoidance of persistence is covered in this chapter in the sections on directed forgetting and retraction.

The Virtues of Forgetting

The seven sins of memory can also be virtues. They occur for a reason and have some adaptive value. Transience and absent-mindedness are helpful because information that is not needed over long periods of time, perhaps because it is no longer relevant, falls out of accessible memory and does not clutter up memory processing. The shift from reproductive to reconstructive processes is particularly helpful when we need to abstract generalities across a wide range of situations, rather than dealing with each new event from scratch. While blocking can occur because we may know so much and have so many experiences, the inhibition that can follow from the management of it helps streamline our thought and makes it more effective and efficient.

Misattribution and suggestibility are consequences of general memory processes that are clearly beneficial. While some things in the world are stable and consistent, others are in flux and are changing. This process allows these needed memory changes to be made. Alternatively, if we learn that our understanding of the world is incorrect, we need to modify our memory. For example, as a young child (like many children) you may have known that the earth is round but thought that it was round like a plate. Or, perhaps, you knew that it was round like a ball, but thought that we lived on the inside of the ball. What you needed to do was alter memory to contain the newer, correct information to update and improve your understanding. These processes are helpful. They are a problem when we update our memories with information that is incorrect. Finally, the persistence of unwanted memories reflects the otherwise desired ability to hold onto information so that it might become useful in the future. This overall benefit is only a problem when the retained information turns out to be troubling or incorrect.

As you will see, one benefit of forgetting is that it causes memories that produce interference to be taken out of the current stream of processing, and thereby be less disruptive. Thus, while the inhibition of memories may seem to be a negative consequence, it can actually be a benefit (Storm, 2011). Forgetting has also been suggested by Nørby (2015) to be helpful and adaptive for emotion regulation (it keeps us from dwelling on previous experiences that swing our emotions too far to the extremes), helping us to be more positive and forgiving. It also allows us to abstract away from the details to conceive of generalities and it helps us disengage from the past, allowing us to focus on the present and the future.

Stop and Review

Forgetting is one of the biggest challenges of memory. Schacter has outlined what he has called the seven sins of memory, namely transience, absent-mindedness, blocking, misattribution, suggestibility, bias, and persistence. While these are described as seven sins of memory, they actually reflect more general memory processes that, on the whole, serve as virtues. On the whole, the process of forgetting likely exists because it is more efficient to lose some information rather than maintain all of it, most of which may become irrelevant or inappropriate.

FORGETTING THROUGH DECAY AND DISUSE

As noted in Chapter 3, there is a predictable pattern of forgetting, as evidenced by the forgetting curve. An intuitive account of this is that as more time elapses without a memory being used, it decays away, and eventually is forgotten. This was called the **law of disuse** (Thorndike, 1914). Although this idea is accepted by some neuroscientists (Hardt, Nader, & Nadel, 2013), the idea of forgetting caused by decay and disuse was rejected by memory researchers following a brutal critique of the idea by McGeoch (1932). In his exposition, McGeoch argued that the passage of time causes nothing by itself. There must be some process that is correlated with time to cause forgetting. An analogy used by McGeoch is the phenomenon of rust. While the amount of rust increases with time, the mere passage of time does not cause rust. Instead it is the oxidation of the metal over time that causes the rust. Thus, the idea that forgetting is a loss of memories over time explains nothing. It is only a description of the phenomenon. McGeoch made a case for the idea that events that occur between learning and testing (i.e., interference) is what causes forgetting. These processes are discussed in detail later.

New Theory of Disuse

After languishing for decades, the idea that decay and disuse can play a role in forgetting was reconsidered in the **new theory of disuse** (Bjork & Bjork, 1992, 2006). This theory does not assume that memories simply decay over time. It acknowledges the fact that the more time that has passed since information was used, the less accessible it becomes, presumably because it is no longer needed. For example, if you move, your previous address may become harder and harder to remember over time, even though it was very well known at one point.

An important distinction for the new theory of disuse is between storage strength and retrieval strength. **Storage strength** is how well a memory is encoded into long-term memory. The more practice a person has with information, the greater the storage strength. In comparison, **retrieval strength** is the ease with which information is retrieved from memory. This distinction between storage strength and retrieval strength is analogous to the concepts of habit strength and reaction potential in the behaviorist learning literature (Hull, 1943). Retrieval strength is strongest just after learning and can increase with greater practice. However, it weakens as new information is encountered, thereby interfering with it. Thus, this is not a pure decay process per se. However, it does reflect the idea that the passage of time corresponds to encountering other information, and the ability to access well-known but unused memories can decline.

PHOTO 8.1 *After a period of time in which memories are not used, they may be*

forgotten to the point where they are not recognized or recoverable

Source: Image Source Pink/Image Source/Thinkstock

One study supporting the new theory of disuse was done by Smith and Handy (2014). They had students at Texas A&M University memorize materials under either constant context or varied context conditions. They then gave memory tests immediately and days later. Context was manipulated by altering background images on a computer screen. While immediate memory was worse in the varied context condition, it was better days later. Why did this happen? The explanation was that with varied contexts this mismatch (following the encoding specificity principle) impairs people's ability to develop retrieval strength because each experience is different. So, memories are not effectively cued early on, and performance was worse. However, each experience with the information does add to the storage strength. These more challenging learning conditions give storage strength a greater boost, thereby improving performance days later. This lends further support to the idea that when you study it is to your benefit to do so in different places at different times of day if you want to maximize your learning.

This view readily explains some memory phenomena. As one example, if people have acquired a skill, such as a golf swing, to a high degree and then learn a new swing, the newer learning will initially overpower the original and dominate performance. However, if the new skill is not continually practiced, the old one will re-emerge, causing a regression to previous ways of thinking and behaving. When you try to change a bad habit, you may be successful immediately, but over time, if you do not continue to focus on changing your ways, the old bad habit will re-emerge. As a more memory-based example, when people learn new information this can produce retroactive interference (detailed below), in which the new memories impede the retrieval of older memories. However, retroactive interference effects weaken over time and the older memories play a larger role. Proactive interference effects, in which the older memories disrupt access to the newer ones, grow stronger (Briggs, 1954; Koppenaal, 1963; Postman, Stark, & Fraser, 1968). This is because the storage strength of an older, well-engrained memory is greater than that for a new memory. As retrieval strength of the newer memory weakens, the greater storage strength of the older memory comes to dominate.

Stop and Review

Early ideas about forgetting suggested that memory traces decay over time.

However, this idea has been largely rejected in favor of mechanisms of interference and inhibition. The new theory of disuse preserves the idea that disuse leads to poorer performance and couches this in a framework that incorporates interference and inhibition.

FORGETTING THROUGH INTERFERENCE

Each experience we have alters memory. Even the act of remembering alters memory because the *experience* of remembering gets stored. One consequence of this multiplication of traces is that memories compete with one another. This com petition is called **interference**. Interference is one of the primary mechanisms of forgetting. When there are two or more traces that have overlapping information, and you only want one of them, interference occurs. Suppose you are trying to remember your friend Mary's phone number. You remember getting the number from Mary when you met her for lunch, but Susan was there, too, and you also got her number. These two memories compete because they both contain phone numbers and the element of having lunch, thereby producing interference. Here, several kinds of interference are covered, including proactive interference, retroactive interference, associative interference, and general interference.

Proactive Interference

Proactive interference occurs when older memories impair the retrieval of new memories (Underwood, 1957). For example, if people study psychology and then study sociology, there is greater forgetting and worse performance on a subsequent sociology test. The degree of proactive interference experienced depends on the overlap between sets of information, not on how much information was learned (Postman & Keppel, 1977). If it is difficult to differentiate between memory traces because of their content, then proactive interference is experienced. This is why sociology and psychology interfere with one another. Any effort that you can make to distinguish and differentiate sets of information reduces the amount of interference, and memory improves accordingly. Proactive interference is resolved by processes in the left lateral prefrontal cortex (BA 46), although the right dorsolateral prefrontal cortex (BA 8) and parietal regions (BA 7) may be involved as well (Nee & Jonides, 2008).

This influence of trace relatedness on proactive interference has been studied extensively. The more related the information in memory is, the more proactive interference that is experienced. Moreover, proactive interference builds up over time until people are given information that differs from the old knowledge. At that point, memory improves and there is **release from proactive interference**. An example of release from proactive interference is a study by Wickens (1970, 1972), in which people were given lists of words to remember (see Table 8.1). The words in the first three lists were all fruits. If the fourth list were fruits again, then memory continued to decline, as shown in Figure 8.1. However, if the fourth list words belonged to a new category, release from proactive interference occurs. Moreover, the greater the difference, the greater the release. For example, vegetables are different from fruits, but they still have some traits in common, whereas professions are quite distinct from fruits.

The build-up and release from proactive interference has even been observed for more real-world materials, such as televised news stories (Gunter, Clifford, & Berry, 1980). As people watched more news stories on a topic (e.g., politics), their memory for each one declined, until there was a switch to a different news story topic (e.g., sports). Why does release from proactive interference occur? It may be because it involves a reduction in the size of the search space (the number of memory traces activated), thereby facilitating retrieval (Bäuml & Kliegl, 2013).

TABLE 8.1 *Stimulus Lists From Proactive Interference Study*

Condition	Trial 1	Trial 2	Trial 3	Trial 4
Fruits (control)	banana	plum	melon	orange
	peach	apricot	lemon	cherry
	apple	lime	grape	pineapple
Vegetables	banana	plum	melon	onion
	peach	apricot	lemon	radish
	apple	lime	grape	potato
Flowers	banana	plum	melon	daisy
	peach	apricot	lemon	violet
	apple	lime	grape	tulip
Meats	banana	plum	melon	salami
	peach	apricot	lemon	bacon
	apple	lime	grape	hamburger
Professions	banana	plum	melon	doctor
	peach	apricot	lemon	teacher

apple	lime	grape	lawyer

Source: Wickens (1972)

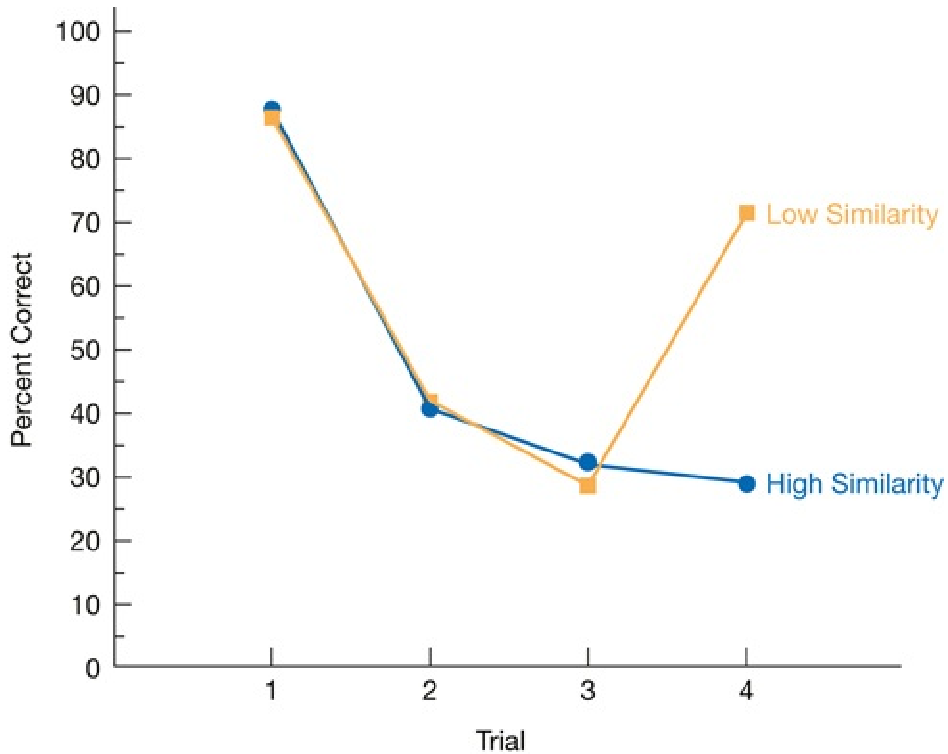

FIGURE 8.1 *Results from a Study of Release from Proactive Interference*

Adapted from: Wickens, D. D. (1972). Characteristics of word encoding. In A. W. Melton & E. Martin (Eds.) *Coding Processes in Human Memory*, pp. 191–215. New York: Wiley

TRY IT OUT

To illustrate the effectiveness of proactive interference on memory and the subsequent release from proactive interference, we will use the example illustrated in Table 8.1. For this project you should have at least 12 people in each group.

Give two or more groups of people the lists of fruit names. Have them recall the words at the end of each list. For all groups, the first three lists should be the same. However, on the fourth list, vary the nature of the list depending on what condition people are in. For one group, give them another list of fruit names. However, for other groups, give them lists of words that are further and further removed from fruits, namely vegetables, flowers, meats, and professions. You don't need all of these groups to do this demonstration but you need at least the first group and one other.

After people are done recalling, collect their responses and tabulate the number of correct recalls for each list. You should find that everyone gets worse from list one to list three, and that at list four the fruit group continues to get worse, but the other groups get better, with the amount of improvement being related to how different the words are from fruits.

Another way to segregate information, causing a release from proactive interference, is by testing people on information prior to the learning of a new set of information (Szpunar, McDermott, & Roediger, 2008). Testing causes a shift in the perceived context of the information, which leads the information to compete less (Pastötter, Schicker, Niedernhuber, & Bäuml, 2011) or because the memories may become more integrated, resulting in fewer competitor memory traces, reducing interference (Wahlheim, 2015).

The experience of proactive interference can be reduced by sleep. Abel and Bäuml (2014) had people learn two sets of information that overlapped in content and which produced proactive interference. Proactive interference was evident for people tested immediately after learning. However, when tested 12 hours later, people who slept (learning in the evening, testing the next morning) exhibited less proactive interference compared to another group of people who were awake during a 12-hour interval (learning in the morning, testing later that evening). The idea is that the process of consolidation served to separate out and distinguish the memory traces from one another, thereby reducing proactive interference.

Retroactive Interference

Retroactive interference is when new memories make it harder to remember old memories (Melton & Irwin, 1940). A classic demonstration of this is a study by Jenkins and Dallenbach (1924), in which students at Cornell University learned lists of 10 nonsense syllables. They were then tested one, two, four, and eight hours later. What is important is what they did during these intervals. They were given the lists either early in the day, so that they were awake the whole time, or at night, so that they were asleep during the retention period. The results in Figure 8.2 show less forgetting when the students slept than when they were awake. When people are awake, there is a continuous stream of new information (including thoughts). This new information produces retroactive interference, making the older information harder to remember. However, if people are asleep, there is not as much new information, so there is less retroactive interference and less forgetting. The degree of retroactive interference benefits from sleep is similar to that observed with proactive interference (Abel & Bäuml, 2014).

With retroactive interference, new experiences make it harder to remember older, similar experiences (Postman & Stark, 1969). For example, if you study psychology and then study sociology, you forget some of the psychology because the newer sociology memories interfere with the retrieval of older psychology information. Alternatively, if you move to a new city, your memory for the new telephone numbers, street names, and stores causes retroactive interference, making it harder for you to remember the city in which you used to live. Retroactive interference is more pronounced with recall than recognition. During recall people try to sort through a large number of competing memory traces, allowing interference to be observed. However, during recognition there are fewer traces involved because a more direct match can be made between the recognition probe and a memory trace. As a result, less interference is observed.

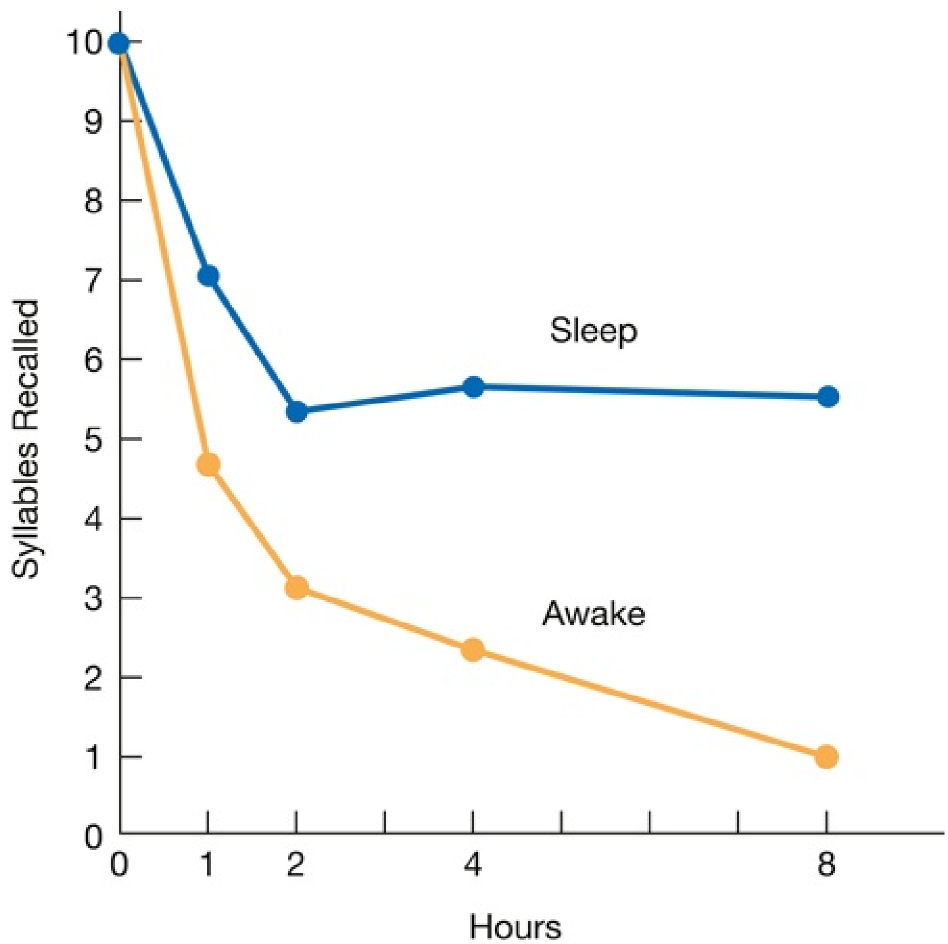

FIGURE 8.2 *Results From a Study of Long-Term Memory Interference*

Adapted from: Jenkins, J. G., & Dallenbach, K. M. (1924). Oblivescence during sleep and waking. *American Journal of Psychology*, *35*, 605–622

In the verbal learning literature, retroactive interference was thought of as a form of behavioral extinction, known as the **unlearning** of prior associations (Barnes & Underwood, 1959; Melton & Irwin, 1940). The idea was that new information causes older information to be lost or disrupted. However, this "unlearning" idea is not completely correct. Retroactive interference can subsequently be reduced or eliminated, suggesting that the original memories are still there, even if they are difficult to access. Thus, retroactive interference may involve a disruption of the retrieval plan that would otherwise be used. If people are given the appropriate cues, then the effects of retroactive interference are attenuated or eliminated (Tulving & Psotka, 1971).

As noted earlier, sleep can help reduce retroactive interference, as in the Jenkins and Dallenbach (1924) study. Sleep also helps by strengthening weaker associations among information brought about by retroactive interference. For example, memory for A–B paired associate lists, after learning A–C lists, is better following sleep, with memory for the A–C lists being unaffected (Drosopoulos, Schulze, Fischer, & Born, 2007; Ekstrand, 1967). That said, if prior, consolidated memories are reactivated prior to learning new information, the prior memories that would have benefited from the consolidation during sleep, reducing retroactive interference, are now susceptible to reconsolidation processes (see Chapter 2) and retroactive interference effects can re-emerge (Deliens et al., 2013).

Associative Interference

Associative interference reflects the complexity of newly learned information. The disruption of memory is not based on temporal order (as it is with proactive and retroactive interference) but on the number of associations with a concept. For example, if you have just learned five things about Jenny, you will be slower to verify any one of these than if you had learned only one thing. Often, associative interference is described in terms of the **fan effect**. The term fan effect assumes that information is stored in a propositional memory network, with nodes representing individual concepts and links representing the associations among them (see Chapter 10). During retrieval, the more links "fanning" off of a concept, the greater the interference from the competing associations and retrieval time increases accordingly.

In a study of associative interference, Anderson (1974) gave students at

Stanford University lists of sentences to memorize, such as “the doctor is in the park” or “the lawyer is in the museum.” The number of associations with the person and location concepts (e.g., doctor or park) was varied from one to three. Thus, there were one to three places that a person could be in, and one to three people in a location. After memorization, a recognition test was given in which students indicated whether probe sentences were studied or not. Unstudied sentences were recombinations of people and locations, such as “the doctor is in the museum.” The results, shown in Figure 8.3, were that, as the number of associations with a concept increased, response time also increased.

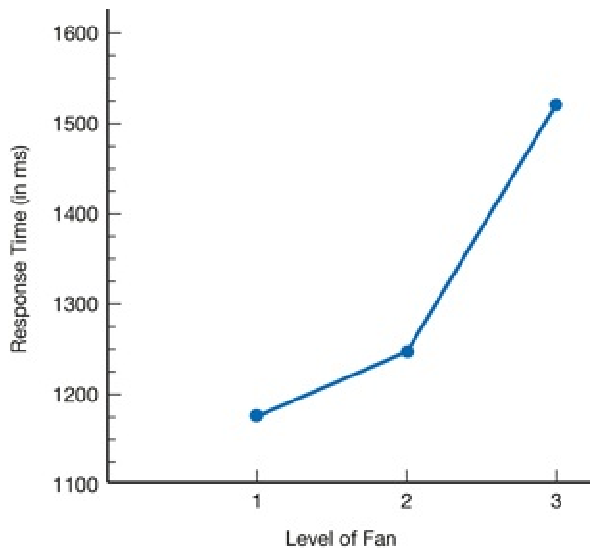

FIGURE 8.3 *Results From a Study of Associative Interference Producing a Fan Effect*

Derived from data reported in: Anderson, J. R. (1974). Retrieval of propositional information from long-term memory. *Cognitive Psychology, 6,* 451–474

A worrisome implication of associative interference is that the more you know, the harder it should be to remember. However, experts in an area actually have more information than novices with no deficit in remembering. This is known as “the paradox of the expert” (Smith, Adams, & Schorr, 1978). A way out of this paradox is to use chunking. Information that is integrated into a common memory trace reduces the amount of interference because there are fewer traces to compete with one another (Radvansky, Spieler, & Zacks, 1993; Radvansky & Zacks, 1991).

Let’s look at chunking in more detail. Suppose people memorize sentences about objects in locations. For some sentences, a single object is in several locations, such as “the potted palm is in the hotel,” “the potted palm is in the barbershop,” and “the potted palm is in the airport.” In these cases, multiple mental models are created, because each sentence refers to a different situation. Thus, there are three memory traces that can compete at retrieval. In contrast, for other sentences, multiple objects are in a single location, such as “the pay phone is in the laundromat,” “the oak counter is in the laundromat,” and “the ceiling fan is in the laundromat.” Here, a single mental model can include all of this information because it all refers to a single event. As such, there is only one memory trace and thus no interference (Radvansky & Zacks, 1991). These differential fan effects are shown in Figure 8.4. This outcome is also observed when people retrieve information from maps that have been studied (Bower & Rinck, 2001).

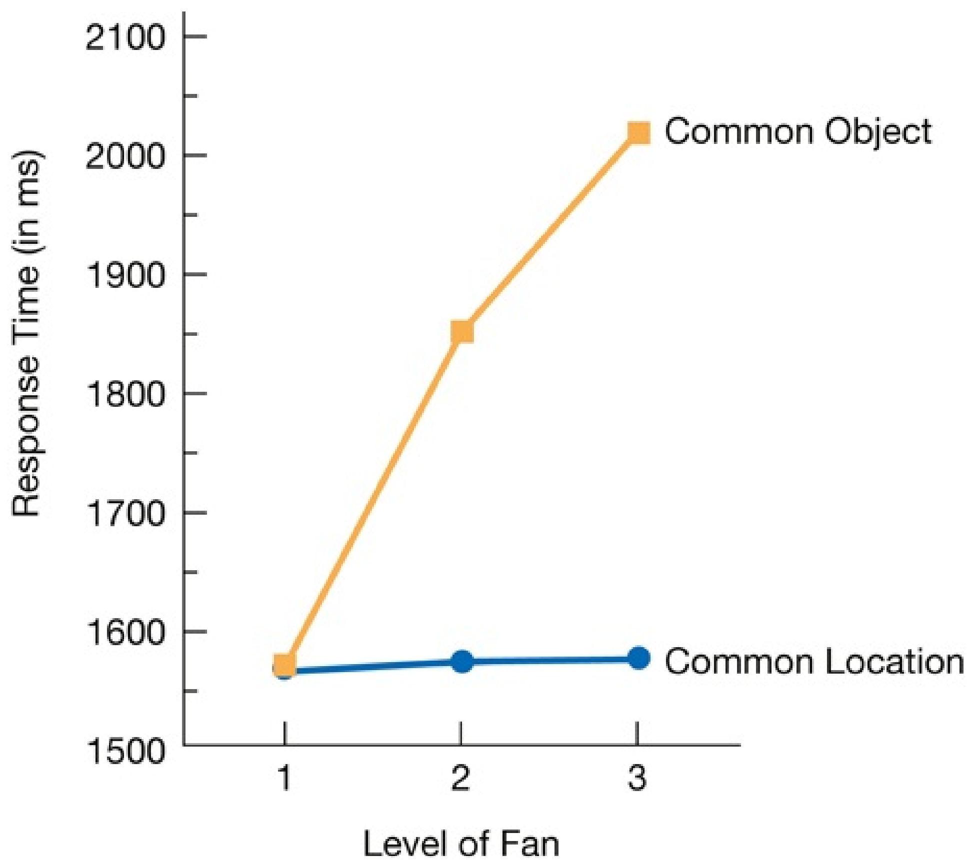

FIGURE 8.4 *Differential Interference Effects When Information Can and Cannot Be Integrated Into Mental Models*

Source: Radvansky, G. A., Spieler, D. H., & Zacks, R. T. (1993). Mental model organization. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 19*, 95–114

Walking Through Doorways Causes Forgetting

Forgetting and interference not only comes knowledge stored in memory; it also comes from our interaction with the events. When we move from one event to another, in the real or a fictional world, there is an **event boundary** (Radvansky & Zacks, 2011). An event boundary is a meaningful change in the ongoing event, such as a change in location, a jump in time, a change in activity, and so on. Encountering an event boundary leads people to set up a mental representation of the new event, called an **event model**. Importantly, memory for the old event is moved out of working memory. Event boundaries are regularly and easily identified by people (Newtson, 1973; Zacks, Speer, & Reynolds, 2009). The organization of information into event models has consequences for memory. To ease exposition, we'll focus on changes in spatial location.

When event models are stored in memory and they have shared elements, such as an object, if people need to retrieve one of them then the related but irrelevant models will produce interference. You saw this at the end of the last section in our coverage of differential fan effects. This event-based interference does not need to involve the memorization of lists of sentences. Just walking through doorways can cause forgetting. In a study by Radvansky and Copeland (2006), people move from room to room in a virtual environment, moving objects from one place to the next. When people walked from one room to another, memory for the objects people were carrying was worse compared to if they had just walked across a large room. In other words, the event boundary disrupted memory. This is not dependent on virtual environments; it is also found with real environments and imagined environments (Lawrence, & Peterson, 2016; Radvansky, Tamplin, & Krawietz, 2010). This parallels work that shows that when there have been shifts in narrative in events, with text and film, people have difficulty accessing information in memory that is tied to the prior events (Swallow, Zacks, & Abrams, 2009; Zwaan, 1996).

At first blush this might seem like a context effect, an instance of encoding specificity (see Chapter 7). When the encoding context does not match the retrieval context, memory is worse. However, this is not what is going on here. If it were, then when people return to the prior room, memory should improve, but it does not. Moreover, if people walk through two doorways, then memory is even worse (Radvansky, Krawietz, & Tamplin, 2011). Also note that this is not an effect of disrupting people while they are trying to updating their understanding a new event (Pettijohn & Radvansky, in press, a, b). The explanation for the forgetting effect is that each room people are in is a different event model in memory. When people pick up an object and move across a room, the object is in just one event model and so there is no interference. However, when people walk into a new room, the object is now in two event models. These event models then compete during retrieval, producing interference. When a person walks through two doorways there are three event models involved and things are even worse.

General Interference and Consolidation

As noted earlier, the more information overlaps in content, the greater the degree of interference. However, there is more to interference than just overlapping content. Think back to the study by Jenkins and Dallenbach (1924). When people slept they experienced less interference. However, the information they learned was nonsense syllables. It is unlikely that they encountered many other nonsense syllables during their daily interaction with the world. So, what must be going on here is that there is general interference that occurs when people process lots of different types of information in their daily activities.

General interference is reflected in **Jost's Law** (see Chapter 3) and the process of consolidation (Wixted, 2004, 2005). Memories are first held in a limited-capacity memory system, such as the hippocampus. When new information is learned, this results in the formation of new memories, which displaces some older memories. This is why there is less retroactive interference following sleep. In general, the older a memory is, the more consolidated it is and the less likely it will be susceptible to general interference. If the formation of new memories is somehow prevented, **retroactive facilitation** can occur in which older memories are actually remembered better.

Improving Your Memory

There is no question that interference is a major contributor to forgetting in memory. Anything that can be done to minimize interference will help reducing forgetting. One way to do this is to make information more distinct in some way, such as using bizarre imagery, different contexts, and so on. Many of these ideas were suggested in Chapter 7. As noted here, and hinted at in other chapters, interference and disruptions of memory that can lead to forgetting is less of an issue for memories that are more consolidated. Anything that can be done to facilitate consolidation should reduce forgetting. This is why taking breaks from studying and doing some quiet resting can improve memory. These rest periods allow knowledge that you have learned to be consolidated, causing forgetting from interference to be reduced.

Another process that may contribute to general interference is neurogenesis. As noted in Chapter 2, neurogenesis is the creation of new neurons. In the hippocampus this may lead to a disruption of the neural patterns for older memories stored there. Keep in mind that, as new information is learned, this increases the possibility that these newly created neurons will stick around and integrate into the pattern of hippocampal cells that is already present. This may disrupt the memory patterns that they are already stored there. In short, the end result is that neurogenesis may cause retroactive interference (Frankland, Köhler, & Josselyn, 2013).

Avoiding Interference Through Resting

As you have seen, encountering other information prior to, after, or overlapping with the memory trace you wish to retrieve can produce interference. Also, sleep can often aid in segregating information during consolidation, thereby reducing interference. That said, one does not need to sleep to reduce interference. Taking some time and simply resting after learning can also reduce interference. For example, a study by Dewar, Alber, Butler, Cowan, and Della Sala (2012) found that resting 10 minutes in between reading two narrative texts boosted memory, both immediately and even a week later.

Stop and Review

Some forgetting is caused by interference from competing memory traces. This interference may come in the form of proactive interference, in which older memories impair the ability to access newer memories, or retroactive interference, in which new memories impair the ability to access older memories. Interference can also be defined in terms of a general overlap among memory traces, as with associative interference. This can even lead to the finding that walking through doorways causes forgetting. Finally, if memories are given time to consolidate, perhaps through a period of quiet resting, there is reduced forgetting from retrieval interference.

FORGETTING THROUGH INHIBITION

Interference in memory is a problem if you want to remember accurately and quickly. One way to reduce and control it is by using **inhibition** to actively reduce the activation of interfering memories. There are a number of ways that inhibition influences memory (Anderson, 2003). That said, inhibiting related but irrelevant memories can also bring about forgetting.

Part-Set Cuing

As you learned in Chapter 7, providing retrieval cues can aid memory. However, there are exceptions. If people try to remember a set of things, such as the names of sports teams, the probability of recalling any one of them is higher if a simple recall test is used than if some of the names are given as cues to help them get started. This counterintuitive finding of poorer memory when provided with partial information is called **part-set cuing** (Nickerson, 1984; Slamecka, 1968). There are two mechanisms that can influence the part-set cuing effect (Bäuml & Aslan, 2006). One is that giving people part of the set disrupts their retrieval plan (Basden, Basden, & Galloway, 1977), similar to the collaborative inhibition discussed later in this chapter.

Another part of the explanation involves inhibition (Aslan, Bäuml, & Grudbeiger, 2007). When people recall an item from a set, it is at a higher level of activation than the rest and it blocks access to the others (Roediger, Stellon, & Tulving, 1977). To reduce the interference from the other items, they are inhibited (Anderson & Neely, 1996). As people get further and further into the set, the unrecalled traces get more and more inhibited, making it harder to recall or recognize them (Oswald, Serra, & Krishna, 2006). So, for part-set cuing, providing people with part of the set leads them to inhibit memory traces that might otherwise have been more available.

TRY IT OUT

Another forgetting phenomenon that you can demonstrate is part-set cuing. For this you need two groups of at least 12 people each. First, for both groups, read everyone a list of 20 words. These words should be read at a rate of about one word per second. Then, after reading all of the words, have people recall them. For the control group, just have the people try to recall all 20 words. However, for the experimental group, first give these people 10 of the words from the original list. Then have them try to recall the other 10. When you are done, collect the response sheets and score the recall performance of both groups only for the 10 words that were not provided to the experimental group. What you should find is that the rate of recalling these 10 words will be worse for the experimental group than the control group.

Negative Priming

Inhibition is also observed with associative interference. By focusing on memories that compete and produce interference, we can assess whether inhibition is operating. If people are probed for interfering memories immediately after they have been inhibited, they are less available (Radvansky, 1999). The decreased availability of memory traces that were recently inhibited is called **negative priming**. It is the opposite of normal (positive) priming, in which related information becomes more available. This is a case of **retrieval-induced forgetting** because remembering one thing makes remembering related things harder. In other words, remembering causes forgetting.

Retrieval Practice

Finally, inhibition occurs when people repeatedly retrieve part of a set of items (Anderson, Bjork, & Bjork, 1994; but see Jonker, Seli, & MacLeod, 2013, 2015). Repeated retrieval causes competing traces to be inhibited. As a result, the probability of recalling the nonpracticed memories decreases (Tulving & Hastie, 1972) as people forget that information faster. This retrieval-induced forgetting for related but unpracticed memories is called the **retrieval practice effect** (Anderson & Spellman, 1995; Storm & Levy, 2012, see Murayama, Miyatsu, Buchli, & Storm, 2014, for a meta-analysis). The study of the retrieval practice effect is detailed in the Study in Depth box overleaf.

The retrieval practice effect can be observed with both recall and recognition (Hicks & Starns 2004; Rupprecht & Bäuml, 2016), as well as indirect memory tests (Camp, Pecher, & Schmidt, 2005). It not only occurs for categorized lists of words but also for sentences with similar concepts (Anderson & Bell, 2001), autobiographical memories as a consequence of episodic future thinking (Ditta & Storm, 2016), and even elements of prose (Saunders & MacLeod, 2006). Thus, it is a pervasive phenomenon.

It is important to keep in mind that the retrieval practice effect occurs only when memory retrieval actually occurs (Saunders, Fernandes, & Kosnes, 2009) and there is some interference present during retrieval for the inhibition to counteract against (Anderson, Bjork, & Bjork, 2000). Merely exposing people to information is insufficient (Ciranni & Shimamura, 1999). This is supported by neuroimaging data, which shows an increase in theta band activity in EEG recordings in cases where there is retrieval interference during a retrieval practice task, resulting in inhibition (Staudigl, Hanslmayr, & Bäuml, 2010).

STUDY IN DEPTH

The retrieval practice paradigm is a frequently used method for assessing retrieval inhibition. To better understand this paradigm, let’s look at an experiment by Anderson and Spellman (1995). For this study, each person received eight lists of words. Four of these were experimental lists and four were untested filler lists to obscure the purpose of the study. Each experimental list had six words in it and all of the words in a list were members of the same category. For example, one person might see words in the categories listed below. Note that some of the items from one category could also be placed in another category. For example, there are some things that are both red and food. The categorized nature of these lists is very important here.

RED	FOOD	FLY	LOUD
blood	bread	kite	thunder
fire	crackers	glider	yell
sunburn	peas	frisbee	traffic
apple	ketchup	butterfly	lawnmower
cherry	radish	eagle	sandblaster
tomato	strawberry	ladybug	compressor

For this study, 48 students from the University of California, Los Angeles, were tested. At the beginning of the study there was an initial learning phase, in which people were shown all of the words in all of the lists. These lists were presented one category–word pair at a time, such as RED–blood, for five seconds each. The point of this phase was to set up the category–word associations in memory.

After the initial learning phase, the experiment went into the retrieval practice phase. Here, people were given a cued recall test in which they saw a category name and the first two letters of the target word, such as RED–bl________. The task was to complete the cued word. People were given 10 seconds to recall each word. Importantly, not all of the categories were tested. Moreover, only half of the items from a practice category were actually practiced. Thus, there were only six items from the list of 24 that actually received retrieval practice, and these items were practiced twice. In addition, all of the words from the four filler lists were practiced once.

To better understand the logic of the retrieval practice phase, use Figure 8.5 as a guide. There were four conditions in this study. Assume that people practiced the first three words in the RED category, and three words from the FLY category. Those practiced items, such as RED–blood, were called the **RP+ items**. These were words from a category that was practiced, and these were the words from that category that were actually practiced. Those words that were from the same category as the practice words, but were *not* actually ever practiced, such as “tomato,” were called the **RP– items**. That is, these were words that were from the category that was practiced but that were never actually practiced. The third condition were words from a nonpracticed category that overlapped words in the practice category, such as “strawberry,” which were called the **NRP-similar items**. That is, these were items that were from a category that was not practiced, but that were similar to items from a category that was. Finally, the fourth condition, words from a nonpracticed category that did not have any overlap with a practiced category, such as “crackers,” were called the **NRP-dissimilar items**. These items will serve as the control condition to assess the influences of retrieval practice and inhibition.

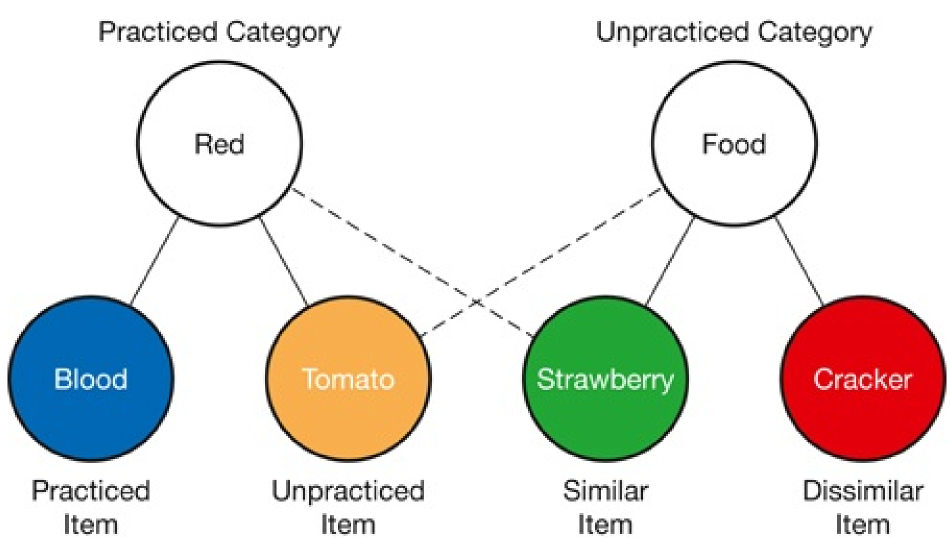

FIGURE 8.5 *Operation of Retrieval-Induced Inhibition in a Retrieval Practice Paradigm*

Source: Anderson, M. C., & Spellman, B. A. (1995). On the status of inhibitory mechanisms in cognition: Memory retrieval as a model case. *Psychological Review, 102,* 68–100

The logic behind this study is that, first, words that were practiced during the retrieval practice phase will be recalled more often later. This is hardly surprising. If you spend more time practicing something, you are going to remember it better than the control items. Second, and of primary importance, is what happens with the RP– items. Because these items are in the same category as the practice items, they are related and irrelevant. As such, they are sources of interference at retrieval during retrieval practice and so they are actively inhibited. They will be recalled less often later than the control items. That is, people will have worse memory for these items because these memories were inhibited. Third, of secondary importance, is what happens to the NRP-similar items. Because they are from a nonpracticed category, memory for them is worse than for those that were actually practiced. However, because they are also similar to the practiced category, there is some spillover inhibition to these items and they are remembered worse than the control items.

After going through the retrieval practice phase, people were given a distractor task to do for 20 minutes to encourage some forgetting (we wouldn't learn much if people recalled most or all of the words). After this distractor task, people were given a cued recall test. For each category, they were given the category names (e.g., RED) and were to recall as many members of that category as they could. People were given 30 seconds for each category. The results, shown in Figure 8.6, revealed that, relative to the NRP-dissimilar condition, words were recalled more often in the RP+ condition, which is consistent with the idea that practice improves memory. Importantly, for the RP– condition, people recalled those words at a *lower* rate, which is consistent with the idea that they were inhibited, making their retrieval more difficult. Finally, also, for the NRP-similar condition, people recalled these words less often, again showing some evidence of retrieval inhibition.

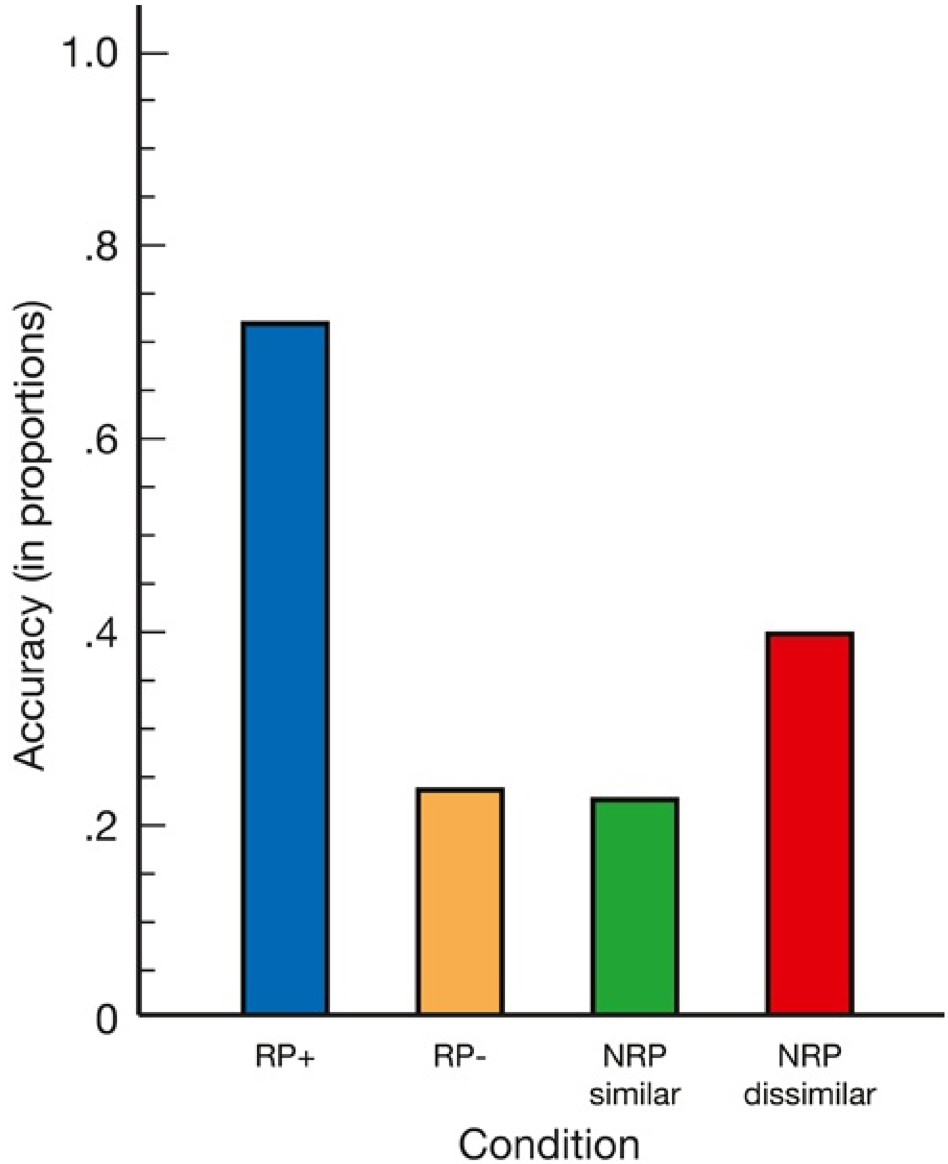

FIGURE 8.6 *Pattern of Recall Rates in Anderson and Spellman's (1995) Retrieval Practice Paradigm*

Created from data reported in: Anderson, M. C., & Spellman, B. A. (1995). On the status of inhibitory mechanisms in cognition: Memory retrieval as a model case. *Psychological Review, 102*, 68–100

The retrieval practice effect can be modified depending on how people think about information. If people can integrate a set of information, then the effect is reduced or eliminated (Anderson & McCulloch, 1999). This is because there are fewer competitors, no interference, and so no need for inhibition. Alternatively, if memory traces are made distinct from one another, this can also reduce the effect by reducing interference (Anderson, Green, & McCulloch, 2000). Finally, consistent with the idea that inhibition is a temporary process used to manage retrieval interference, retrieval practice effects are reduced or eliminated after longer delays (e.g., a day later), after inhibition has dissipated (Abel & Bäuml, 2012, 2014).

Stop and Review

Interference experienced during retrieval disrupts memory. This interference is reduced through inhibition, thereby facilitating the retrieval of target memories. However, this also makes the retrieval of inhibited memories more difficult. This is retrieval-induced forgetting. This is seen in part-set cuing, in which people who are given part of a set of information find it harder to retrieve the rest of the set, compared to if no cue is provided. Similarly, with negative priming, memories that were just previously sources of interference are responded to more slowly. Finally, the retrieval practice paradigm shows that repeatedly retrieving part of a set of items can make the rest of it harder to recall later.

INTENTIONAL FORGETTING

Most of the topics of forgetting covered here are about ways that people forget things that they would prefer to remember. However, there are times when we don't want to remember and instead we want to forget. An everyday example of this would be if someone were telling you their phone number and then realized they had given you the wrong one and said, "Oh, wait, that's not the number, the number is . . ." Clearly you would want to forget the incorrect information. In this portion of the chapter we cover two lines of research involving intentional forgetting. These are research on directed forgetting and retraction.

Directed Forgetting

The first type of intentional forgetting is when people are explicitly told to forget some material and to remember others. This is **directed forgetting** (Bjork, 1970). The effectiveness of directed forgetting is assessed on a final memory test in which people are to retrieve all of the prior information, both things that they were told to remember and the things that they were told to forget. There are two hallmarks of the directed forgetting effect (relative to a control condition in which people are told to remember everything). The first, obviously, is that the to-be-forgotten (TBF) information is remembered worse. The second is that the to-be-remembered (TBR) information is remembered better. There are three methods for studying directed forgetting. These are item method directed forgetting, list method directed forgetting, and selective directed forgetting. Each of these is considered in turn.

For **item method directed forgetting**, people are given a set of items and after each item they are explicitly told either to remember (TBR) or forget it (TBF). The explanation for the directed forgetting effect here is that when people are told to forget an item they stop rehearsing it, so it is not stored in memory. In the absence of such rehearsal, those TBF items that are retrieved on a final memory test also appear to be more impoverished than the TBR items (Fawcett, Lawrence, & Taylor, 2016). In contrast, people devote more attention to the TBR items and rehearse them, causing them to be better remembered (Basden, Basden, & Gargano, 1993).

For **list method directed forgetting**, people are given a list of items. Then they are told either to remember that list (control condition) or to forget it (experimental condition). Afterward, people are given a second list. Under these conditions, people need to rehearse all of the first list items prior to the forget instruction, because they don't know that they will be told to forget it. The dominant explanation for this kind of directed forgetting is that people inhibit the TBF information in memory (Basden et al., 1993; Bjork, 1989). This inhibition is effortful. If people are disrupted by a secondary task, the inhibition of TBF information is reduced or eliminated (Conway, Harries, Noyes, Racsmány, & Frankish, 2000). Note also that list-based directed forgetting is alleviated by a night's sleep (Abel & Bäuml, 2012; but not for naps: Saletin, Goldstein, & Walker, 2011). The consolidation that happens during sleep causes a lifting of the inhibition of memory traces.

The inhibition of the TBF information is pervasive. It occurs both for direct memory tests, such as recognition and recall, and for indirect tests, such as word fragment completion and repetition priming (MacLeod, 1989). Directed forgetting can be extended to autobiographical memories (Barnier et al., 2007). It also occurs for enacted tasks (things that you do rather than only think about or watch), although to less of a degree for verbal information (Sahakyan & Foster, 2009). Directed forgetting is reduced if the TBF items are meaningfully (semantically) related to TBR items (Conway et al., 2000). Presumably, the automatic priming of the TBF items by the TBR items keeps it from being effectively forgotten.

Note that, while the inhibition account is the dominant explanation, it also possible for directed forgetting can be brought about by changes in (mental) context (Sahakyan & Kelley, 2002). The idea is that when a person gets a cue to forget something, this instruction sets up a change in the mental context. As a con sequence, a mismatch in mental context impairs the ability to access information in memory, much as is seen with encoding specificity (see Chapter 7).

For **selective directed forgetting**, people are given a set of information and then are told to forget only part of it based on some criterion. For example, a person might be told a bunch of facts about Tom and Bill in a random order. Then they are told to forget everything about Bill. After this, they then learn a bunch of facts about Steve. This is selective directed forgetting because people are not told to forget things on an item-by-item or listed base manner. Instead, they are to selectively edit memory based on some common concept, such as a person.

Selective directed forgetting is absent if the materials are highly integrated, perhaps because the various components of the set of materials continue to prime and activate the information that was marked as TBF. As a net result, the set of materials continues to be remembered rather than forgotten (Delaney, Nghiem, Waldum, 2009; Sahakyan, 2004). It should be noted that directed forgetting results have been difficult to replicate, and there have also been some failures to do so (Storm, Koppel, & Wilson, 2013). So, while selectively forgetting based on some idea, person, or event seems like it should be possible, and feels like something we do regularly, our understanding of how we actually go about doing this is not well understood at this time.

Retraction

Related to directed forgetting is the idea that sometimes we learn things that we later learn are incorrect. Information that we encounter is first treated as accurate until we have a motivation to think otherwise (Gilbert, Krull, & Malone, 1990). When information is then marked as incorrect it is said to be **retracted**. In general, while retraction does have some influence on memory, people do have some difficulty altering their knowledge and understanding.

In an early study by Kay (1955), students at Cambridgeshire Technical College were given two stories to read for later recall. They then recalled the stories immediately and then five more times over the next four months. Importantly, people were given another opportunity to reread the stories after each recall attempt. What was striking was that when people made an error in the recall of the story the error typically persisted throughout the additional attempts, even though there was an opportunity to correct the mistake after each rereading.

Given this resistance to modifying one's understanding, it is best to try to understanding something correctly the first time, to as great a degree as possible.

An interesting thing about retracted information is that the retracted knowledge continues to influence our inferences, judgments, and decisions. Thus, it is called the **continued influence effect** (CIE) (Wilkes & Leatherbarrow, 1988). For example, if people are told that a traffic accident involved older adults, and later this information is retracted, people may continue to make age-related inferences about the injured, such as suggesting that the family members who would need to be contacted would be their children (with no mention of other possibilities, such as parents). As a real-world example, during the 2003 Iraq War misinformation was sometimes reported by news outlets, such as a report that Iraqi forces were executing coalition prisoners of war. Afterward, this misinformation had be denied or corrected by the news agencies. However, some people continued to use it (Lewandowsky, Stritzke, Oberauer, & Morales, 2005). As another example, Greitemeyer (2014) found that some scientists continue to believe results that had been retracted (e.g., if it had been found that someone faked the data).

The CIE is quite robust. It not influenced by whether the retraction is given immediately or after a short delay (Johnson & Seifert, 1994). That said, the CIE does require that the retracted information be part of the larger event. It is not observed if it was merely mentioned in passing (Johnson & Seifert, 1994). Finally, the magnitude of the CIE effect can be reduced if people are given an alternative causal explanation for the described event (Ecker, Lewandowsky, & Apai, 2011), such as being told that the injured in an accident were not older adults but were patients at a local rehabilitation center.

Stop and Review

Not all types of forgetting are a problem. Sometimes we have good reason to forget. For directed forgetting, people are told to forget things and they do so. This can also increase memory for other information. This can be done on either an item-by-item basis, resulting in differential rehearsal, or a list-based basis, resulting in the inhibition of to-be-forgetten information. We also seem to have the ability to selectively forget information, but how this is done is not well understood. Other times, we need to forget things that turn out to be wrong and were retracted, but are only partially successful at doing this.

SOCIAL INFLUENCES

Many of the studies discussed here have a person largely remembering alone. However, in the real world, people are in social situations, interacting with others in complex ways. These other people can influence memory. For example, people remember events differently depending on who they are with (who they are telling their story to), which can then bias later memories for the event (Tversky & Marsh, 2000). Moreover, people who work with high-performing individuals recall more than people who work with low-performing individuals (Reysen, 2003). Finally, people remember information better if they think the material comes from another person as compared to a computer (Reysen & Adair, 2008). Even how well we remember someone's face depends on social influences. People remember faces better when the person in the picture is looking at them than when they are looking away (Mason, Hood, & Macrae, 2004). Thus, memory is influenced by other people. In this section we look at how interacting with other people can promote forgetting, as well as some evidence that it can have the opposite effect.

Collaborative Inhibition

Research has found that when people in groups try to recall something, they typically recall less than if they were separated, asked to recall information, and had their individual efforts pooled (Basden, Basden, Bryner, & Thomas, 1997; Rajaram & Pereira-Pasarin, 2010; Weldon & Bellinger, 1997). This decline in memory when working in a group is collaborative inhibition. In other words, overall, people recall less in a group than as individuals.

Collaborative inhibition does not reflect social loafing. Instead, people are encountering different ways that other individuals have structured the information. Each person's recalls are based on his or her own retrieval plan. When confronted with an organization that is inconsistent with one's own retrieval plan, the ability to recall becomes disrupted and performance declines (Finlay, Hitch, & Meudell, 2000; Weldon, Blair, & Huebsch, 2000). This is related to the part-set cuing phenomenon (but see Kelley, Pentz, & Reysen, 2014). Not only is some information forgotten when it is recalled in groups but the shared memory of an event becomes more homogeneous across the group members, both in terms of its content and its organization (Congleton & Rajaram, 2014).

People can insulate themselves against collaborative inhibition if they spend some time retrieving information on their own prior to retrieving in a group setting. That is, the testing effect (Chapter 7) may guard against collaborative inhibition (Congleton & Rajaram, 2011). It should be noted that, although people recall more as individuals than in groups, recalling in groups does increase the accuracy of the information that actually is recalled (Harris, Barnier, & Sutton, 2012; Vollrath, Sheppard, Hinsz, & Davis, 1989).

Also, when people recall events together, this can result in the inhibition of unrecalled aspects of their memories. In other words, this is a form of retrieval practice effect both for the people who originally spoke and for the people who were only listening (Coman & Hirst, 2012; Coman, Manier, & Hirst, 2009; Cuc, Koppel, & Hirst, 2007). Thus, the same memory processes that lead to forgetting in an individual can be triggered just by listening to other people.

PHOTO 8.2 *While working collaboratively with others can often be beneficial, there is some evidence that collaborative memory retrieval can actually be worse (something called collaborative inhibition) than working alone and summing the groups' efforts*

Source: moodboard/moodboard/Thinkstock

Collaborative inhibition not only applies to cases in which a person is trying to retrieve information either alone or in a group; it can also occur when people learn or encode information (Barber, Rajaram, & Aron, 2010). This is even true if the same people are present at learning and retrieval (so it is not poorer memory as a result of a change in social context). The problem that can occur when learning with other people is that different people create and use different retrieval cues from each other. When people study together, they do not develop the retrieval cues that would be most helpful for their recall of the information.

This is also the reason why people do not learn as well by using other people's class notes (Annis & Davis, 1975). That said, it should also be noted that it is possible for collaborative encoding to mitigate effects of collaborative inhibition at retrieval, in some sense shifting where the memory problems are originating from (Harris et al., 2012).

Collaborative Facilitation

Working with groups is not all bad and doesn't always lead to forgetting. Although memory is worse on recall tests in groups than alone, the opposite is true for recognition (Hinsz, 1990; Vollrath et al., 1989). This is collaborative facilitation. In recall, the retrieval plan plays an important role in performance. In contrast, in recognition there is no retrieval plan. Memory only requires that something seem familiar, and anything more is a bonus. When people do recognition in groups, they can pool their resources to arrive at a consensus about what happened, although this is more effective at accepting old items than rejecting new items (Clark, Hori, Putnam, & Martin, 2000).

Other People's Memories

In addition to the influence of other people on our own memories, we may also be called upon to evaluate the quality of other people's memories. While we can do this to some degree, there are some biases that can creep up. One is the *consensus bias* (Ross, Greene, & House, 1977), which is the idea that we often assume that other people know what we know. So, if we have an idea, we implicitly expect other people to know this as well.

Another bias is that people expect others to do better when the pressure is on to remember something. While motivation to remember can help when people first encoding something, it does not help much, if at all, during retrieval. However, we often expect other people to remember more when they are motivated to do so (Kassam, Gilbert, Swencionis, & Wilson, 2009). Imagine high-profile court cases in which people are strongly motivated to remember something accurately. If they were trying to remember at the time the event occurred, then it is reasonable to expect that memory will be better. However, if they were only motivated by hindsight to retrieve something that did not seem particularly important at the time, then memory will be relatively poor regardless of the desire to remember. Despite this, we often expect other people to remember better because of a lack of insight we have into how memories work.

Stop and Review

Interacting with other people can also cause forgetting. This collaborative inhibition occurs when people recall less in groups. This may be a result of a disruption of people's retrieval plans and the inhibition caused by socially induced retrieval practice. That said, collaborative facilitation can happen, as with recognition memory. Another problem that can arise when we interact with other people is our blindness to how well other people's memories work. People often cannot remember more just by trying harder, even at our (incorrect) insistence.

DRUGS AND ALCOHOL

Forgetting not only occurs as a natural part of memory, or through our interaction with others, it can also occur as a result of chemicals that we put into our bodies. In this section we look at the influence of drugs and alcohol, which produce changes in memory and forgetting.

Drugs

One class of drugs that has a strong influence on memory is **benzodiazepines** (e.g., Valium and Halcion), which are depressants. These drugs influence memory by increasing GABA-related processes, which inhibit neural firing. Because of this suppressed neural activity, people taking these drugs have difficulty acquiring new memories. In a sense, this is a drug-induced form of anterograde amnesia without retrograde amnesia, similar to what is seen in Korsakoff's patients (Curran, 1991). In other words, these drugs cause forgetting by impairing the ability to encode new knowledge. Benzodiazepines primarily compromise declarative rather than non-declarative memory (Reder et al., 2006), with PET scans on one study showing suppressed processing in the right prefrontal cortex (BA 9), left parahippocampal gyrus (BA 35), and left anterior cingulated cortex (BA 32) (Mintzer, Kuwabara, Alexander, Brasic, Ye, Ernst, Griffiths, & Wong, 2006).

A beneficial consequence of drug-induced anterograde amnesia is that retro active interference effects are diminished. Memory for information learned prior to taking the drug is better than it would be otherwise (Fillmore, Kelly, Rush, & Hays, 2001). Because new memories are not created, they cannot interfere backward in time to cause retroactive interference. In addition, although memory is typically better for emotional information, people taking benzodiazepines do not show this benefit, suggesting that the drugs are also disrupting amygdala processing (Buchanan, Karafin, & Adolphs, 2003).

Alcohol

Another substance that can influence memory is **alcohol**. Alcohol can have a number of effects, although the focus here is on the consequences of individual episodes of drinking. In general, memory is worse for things learned while under the influence of alcohol, although this may be primarily for peripheral and secondary information (Schreiber Compo et al., 2011). Alcohol affects a broad range of memory processes (Maylor & Rabbitt, 1993), including executive working memory function (Saults, Cowan, Sher, & Moreno, 2007) and prospective memory (Leitz, Morgan, Bisby, Rendell, & Curran, 2009), and it produces overconfidence in metamemory judgments (Nelson, McSpadden, Fromme, & Marlatt, 1986). Work using the process dissociation procedure has shown that alcohol's influence is more pronounced for explicit, declarative knowledge than for implicit, nondeclarative knowledge (Kirchner & Sayette, 2003; Ray & Bates, 2006). Part of the problem is that alcohol, as EEG recordings show, disrupts event-related synchronization and desynchronization (see Chapter 2) in the cortex in the theta and alpha band levels (Krause et al., 2002). Thus, the brain cannot coordinate processing as effectively when people consume alcohol. At high enough blood alcohol levels, people can experience blackouts, during which there is no memory for any of the events of that time period. This is a sign of a serious drinking problem.

In addition to the negative effects of alcohol on memory, there are some positive effects as well. Specifically, information is remembered better if people consume alcohol immediately afterward than if they do not (Moulton et al., 2005). This is another example of retroactive facilitation. One theory is that because information is so poorly encoded when one is under the influence of alcohol there are fewer new memory traces to produce retroactive interference. Another line of thinking is that alcohol may actually facilitate consolidation of the earlier memory traces, perhaps because of increased glucose levels (Scholey & Fowles, 2002).

Alcohol can even influence memory when it is not actually present but when it is just suggested to people that they have consumed alcohol. Assefi and Garry (2003) had students at Victoria University of Wellington watch a slide show involving a man shoplifting at a bookstore. Later, people were presented with misleading postevent information (see Chapter 14). Even though all of the students drank tonic water, half of them were told that the water also contained vodka (the glasses were rimmed with vodka). Students who thought that they drank alcohol were more susceptible to the misleading information and were more confident in their responses, in a pattern consistent with actual alcohol consumption. So, just the thought of drinking alcohol can influence how people use their memories and what they forget.

Stop and Review

Forgetting can be caused by external influences. Some drugs, such as benzodiazepines, block normal operations of the nervous system resulting in a drug-induced amnesia. Alcohol can also disrupt the formation of new memories. In both of these cases, there can be the blocked formation of new memories reduces retroactive interference, allowing for a retroactive facilitation effect.

PUTTING IT ALL TOGETHER

The opposite of remembering is forgetting. Forgetting is often seen as a negative thing, almost a sin. This negativity absence of memories is more likely when there is competition among several memories, producing interference during retrieval. This can happen proactively, retroactively, associatively, and generally. It’s everywhere, like a plague. This inference can cause you further difficulties when the process of inhibition is involved, causing some memories to be even harder to retrieve than before as they are pushed below their prior levels of accessibility. This is seen with the part-set cuing, negative priming, and retrieval practice effects.

However, in an adaptive sense, forgetting allows you some control over your thoughts, keeping them from becoming clogged with irrelevant information. A sin may actually be a virtue. When knowledge ceases to be relevant, forgetting causes it to become extinct through disuse, even if the passage of time itself is not sufficient to cause forgetting. Here the positive absence of memories comes about as interference keeps old and unwanted information at bay. While the interfering memories that have been inhibited are harder to access, this inhibition is very helpful in controlling the negative effects of interference. This inhibition can also be deliberately used to keep incorrect and irrelevant knowledge out of mind, as can occur with directed forgetting and retraction. The net result is that forgetting keeps away unwanted knowledge and promotes the remembering of wanted knowledge. Forgetting is everywhere, taking out the garbage and keeping things fresh.

Most of the forgetting that was considered here derives from the normal use of memory. Forgetting is just something that happens. However, forgetting can also be brought in from the outside. This happens when you interact with other people, as with collaborative inhibition, and when you take certain drugs and alcohol. Even walking through a doorway can cause forgetting. On the whole, forgetting is not just a part of yourself but is also part of how you interact with the world.

STUDY QUESTIONS

1. What are Schacter's seven sins of memory? How might these actually be virtues?
2. How does the passage of time influence forgetting? What is the law of disuse?
3. What is Bjork's new theory of disuse and what are its core principles?
4. What is negative transfer and how is it an interference theory of forgetting?
5. What is proactive interference and how is it an interference theory of forgetting? How does proactive interference differ from negative transfer?
6. What is the release from proactive interference and how can it be brought about?
7. What is retroactive interference and how is it an interference theory of forgetting?
8. What is associative interface and how does it produce the fan effect? How does the integration of information in memory cause a reduction in associative interference?
9. What is the role of inhibition in memory retrieval? How does this manage interference? How does this cause forgetting?
10. What are some of the effects that are produced by the operation of inhibition?
11. In what circumstances do people intentionally forget information?
12. What is directed forgetting? What are the different ways of bringing this about? What is the cause of directed forgetting in each of these circumstances?
13. What does it mean for information to be retracted, and how well does memory handle retracted information?
14. What are ways in which social settings can actually promote forgetting? What are ways in which it promotes remembering? How well do we

understand other people's memories?

15. What are the influences of drugs, such as benzodiazepines and alcohol, on remembering and forgetting?

KEY TERMS

- absent-mindedness
- accessibility
- alcohol
- associative interference
- availability
- benzodiazepines
- bias
- blocking
- collaborative facilitation
- collaborative inhibition
- continued influence effect (CIE)
- cue overload
- directed forgetting
- event boundary
- event model
- fan effect
- forgetting
- inhibition
- interference
- item method directed forgetting
- Jost's Law
- law of disuse
- list method directed forgetting
- misattribution
- negative priming
- new theory of disuse
- NRP-dissimilar items
- NRP-similar items
- part-set cuing
- persistence

- proactive interference
- reconstructive
- release from proactive interference
- reproductive
- retracted
- retrieval-induced forgetting
- retrieval practice effect
- retrieval strength
- retroactive facilitation
- retroactive interference
- RP+ items
- RP- items
- selective directed forgetting
- seven sins of memory
- storage strength
- suggestibility
- transience
- unlearning

EXPLORE MORE

Here are some additional readings for you to explore to get a deeper understanding of the issues involved in long-term memory forgetting.

Bjork, R. A., & Bjork, E. L. (1992). A new theory of disuse and an old theory of stimulus fluctuation. In A. Healy, S. Kosslyn, & R, Shiffrin (Eds.), *From Learning Processes to Cognitive Processes: Essays in honor of William K. Estes* (pp. 35–67). Hillsdale, NJ: Erlbaum.

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NOTE

1 Multitasking while trying to learn is a very bad idea.

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CHAPTER 9

Semantic Memory

Sometimes our memories do not refer to specific events but are more encyclopedic. This general knowledge is **semantic memory**. This type of memory allows us to take advantage of regularities in the world to make more accurate predictions about what will happen next. For example, if all you had to go on were episodic memories of specific instances, then every time you encountered a dog you would need to start all over again figuring out the safety of the situation and how you should react. Every time you saw a new chair, you would need to determine what its purpose was. Every time you went to a new restaurant, you would have to learn the procedure for getting some food. Semantic memories are generalizations that apply to a wide variety of similar circumstances.

In this chapter we cover a number of aspects of semantic memory. We first address the issue of semantic memory organization and how it provides not only the information we may need at the time but also other related information that is likely to be relevant. This is semantic priming. We then examine two classes of semantic memories and how we use them to understand our world. One is how categories are structured and used. We will also see how ordered relations are represented and how they influence memory more generally. Another type of semantic memory is scripts and schemas for commonly experienced aspects of life. Finally, we spend some time looking at cases where semantic memory falls short.

SEMANTIC PRIMING

A salient characteristic of semantic memory is its organized and regular structure. Remembering one **concept** brings related memories closer to awareness. This facilitation of related ideas is **priming** (Meyer & Schvaneveldt, 1971). Semantic memory is structured based on shared aspects of meaning (Thompson-Schill, Kurtz, & Gabrieli, 1998) and similar concepts are metaphorically stored closer together. When a concept is activated, this activation spreads to related concepts. Because they are more activated, if there is then a need to use them they are now closer to conscious awareness and can be used more readily. Note that concepts don't need to be abstract ideas in memory but can be anything people are thinking about, including their emotional state. For example, people respond faster to happy words such as "peace" when in a happy mood and faster to sad words such as "die" when in a sad mood (Olafson & Ferraro, 2001).

In a typical priming study, people are given a lexical decision task. That is, they are given strings of letters and asked to indicate whether they are words. For example, "doctor" is a word, but "dohter" is not. In these studies, there are pairs of words: a critical item, called a **prime**, is followed by a **target**. What is of interest is how fast people respond to the target (such as by pressing a button). If the prime is unrelated to the target, this is a baseline, *control* condition—for example, if the target "doctor" is preceded by the prime "potato." If the prime is semantically related to the target, this is the experimental condition—for example, if the target "doctor" is preceded by the prime "nurse." People are faster to respond to a target in the *experimental* condition relative to the control. Priming is even observed in ERP recordings as early as 250 ms after the target word is presented (Bentin, McCarthy, & Wood, 1985). This is because it is easier for the brain to activate that information, so it doesn't need to work as hard.

Semantic priming occurs because concepts are not understood in isolation but in terms of how they relate to each other. By activating related concepts, people bring to bear a larger set of knowledge to help them understand and think. For example, when you listen to a lecture you need a broad understanding of what is being discussed. You do not just narrowly think about the specific words and concepts being said.

Priming also helps people detect inconsistencies. When people encounter semantically anomalous information, such as hearing the sentence "the doctor listened with his carrot," ERP recordings show an increased electrical negativity around 400 ms after first seeing it (Kutas & Hillyard, 1980). This semantic inconsistency detection is called the N400. That is, when memory processing was surprised by the anomalous information, it starts working harder to figure out what is going on.

Mediated Priming

The theory behind semantic priming is that when a concept is activated, this activation spreads to related concepts. From this perspective, one question is how far does this spread go? Do only those concepts that are directly related to the first receive this spreading activation, or does it go beyond that? For example, when retrieving the concept “lion” it is likely that the concept “tiger” is activated because these are both large, predatory cats. If “tiger” is primed, are concepts related to it also activated, such as “stripes”? This would be **mediated priming** because the connection between “lion” and “stripes” is mediated by “tiger.”

In general, mediated priming does occur (Balota & Lorch, 1986; McNamara & Altarriba, 1988), as shown by using both response times and ERP recordings (Hill, Strube, Roesch-Ely, & Weisbrod, 2002). However, mediated priming is more fragile than direct priming. Its priming is smaller in magnitude and it is sometimes not observed (De Groot, 1983).

STUDY IN DEPTH

Priming is generally a more or less automatic, implicit process. Still, it is possible for it to be affected and redirected by conscious effort. This was shown in a study by James Neely (1977). In this study, 122 students at Yale University were given a series of category names followed by a lexical decision task. That is, people saw a category label, such as BIRD, followed by a string of letters, such as “bluejay,” with the task of indicating whether that string was an English word. These lexical decision probes came 250, 400, or 700 ms after the category label. This difference between the onset of the category and the lexical decision probe is called the stimulus onset asynchrony, or SOA.

There were five conditions in this study. The pattern of results for each of these conditions is shown in Figure 9.1. The first condition was *Nonshift–Expected–Related* in which people expected that if a word followed the category name it would be a member of that category, and it was—for example, seeing the category BIRD followed by the word “robin.” As can be seen in Figure 9.1, consistent positive priming was observed at all SOAs.

A second condition was Nonshift–Unexpected–Unrelated, in which people expected that if a word followed the category name it would be a member of that category, but it was not—for example, seeing BIRD followed by “arm.” Looking at Figure 9.1, there is initially no effect on response time but later people are slower to respond because the activation has all been directed to the BIRD portion of semantic memory. Thus, it takes time to disengage and move to another part of semantic memory.

The third condition was *Shift–Expected–Unrelated*, in which people expected that when a word followed a category name it would be a member of a certain unrelated category, and it was. An example of this would be seeing BODY followed by “door” when a building part was expected. As shown in Figure 9.1, positive priming develops over time. If people expect a building part when they get BODY, they can activate that portion of semantic memory, but this takes time.

The fourth condition, *Shift–Unexpected–Unrelated*, was similar to the third, except the word was a member of an unrelated category—for example, seeing BODY followed by “sparrow.” As shown in Figure 9.1, there is initially some negative priming and this gets larger over time. Because people expect a building part when they get BODY, they consciously activate the building portion of semantic memory. It requires effort to disengage this activation and move it.

The fifth condition was *Shift–Unexpected–Related*, which is similar to the previous two except that the word was a member of the same category as the prime—for example, seeing BODY followed by “heart.” As shown in Figure 9.1, initially there is some positive priming. An automatic process activates the part of semantic memory associated with the category name. However, over time, people shift activation to another part of semantic memory. As such, they need more effort to disengage from what is expected and move back to the original portion. This pattern of response times is supported by EEG recordings that show that the automatic activation of information emphasizes the parieto-temporal cortex, whereas the conscious evaluation of semantic information emphasizes the frontal lobes (Krause, Gibbons, & Schack, 1998).

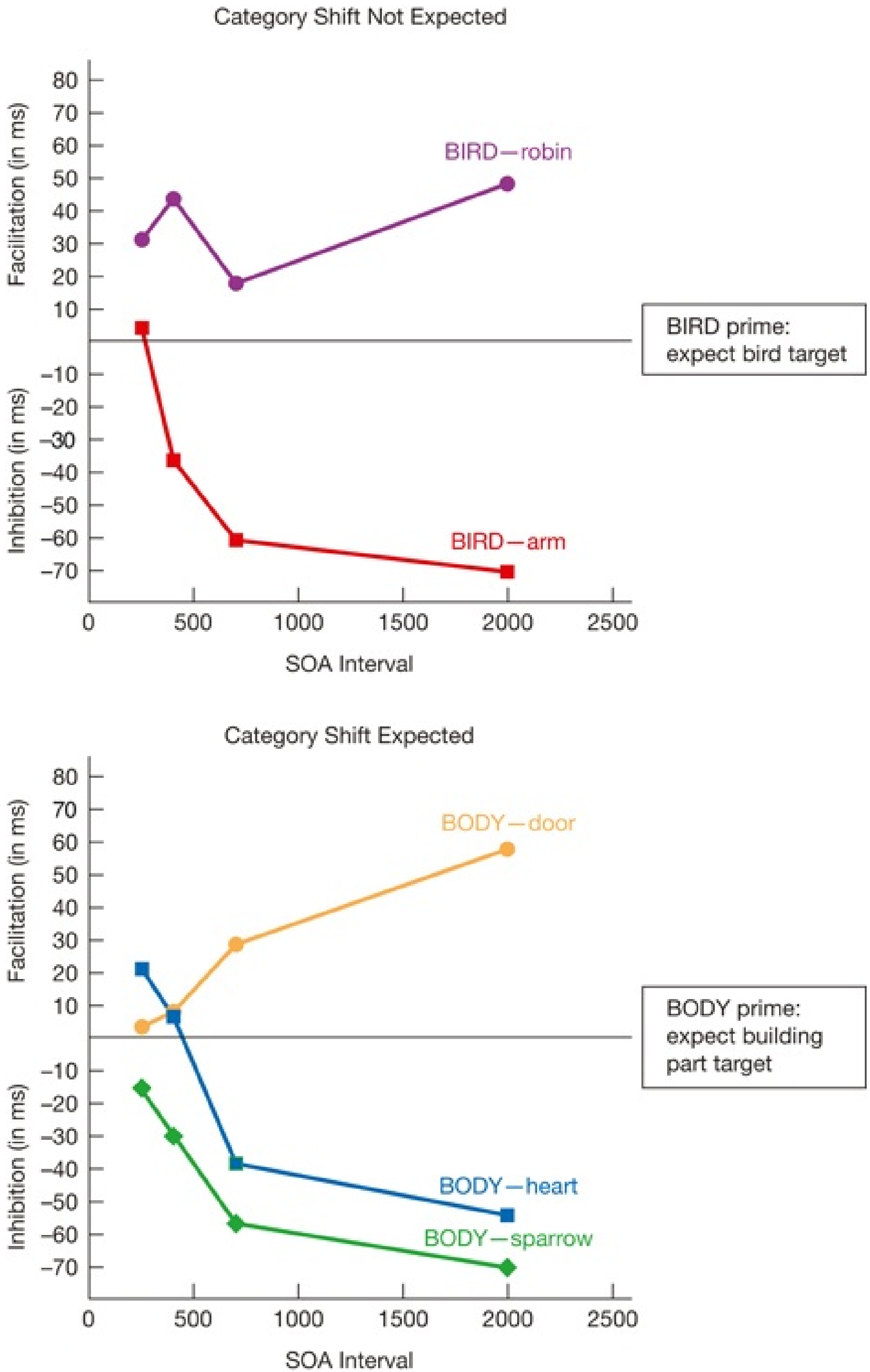

FIGURE 9.1 *Automatic and Controlled Priming in Semantic Memory*

Source: Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, 106, 226–254

Semantic Interconnectivity

In episodic memory, increased numbers of associations with a concept can slow down retrieval time, as in the fan effect. Semantic memory is made up of very large numbers of associations among concepts. This interconnectivity can be thought of as a complex network of concepts and associations (see Chapter 10). And so, based on the fan effect, one would expect that it should be difficult to retrieve semantic information. However, the opposite is true. Specifically, concepts in semantic memory that have more interconnections are retrieved faster (Ashcraft, 1978; Kroll & Klimesch, 1992).

This different pattern of results is observed because in semantic memory these associations provide both direct and indirect connections among concepts. Two concepts might be directly associated but also share a number of intermediate concepts, which functionally increases the number of retrieval pathways between them. As a result, there are many ways that concepts can prime one another. The more indirect connections there are, the more likely any one of those pathways will be activated after a given period of time. Think of this as a horse race. If there are lots of horses running, the race will likely be over faster than if only a few horses are racing because it is more likely that there will be a fast horse in the bunch.

Inhibition

Like episodic memory, **inhibition** can be used to help narrow a memory search to the appropriate part of semantic memory. During retrieval, related concepts may be inhibited. For example, people retrieve the concept “salmon” for the category FISH more slowly if they had recently retrieved several other examples of fish. Specifically, this inhibition occurs because people actively retrieve information than if they are passively reading (Blaxton & Neely, 1983; Johnson & Anderson, 2004). The need to select a specific semantic memories can cause the inhibition of related competitors that could otherwise produce interference.

Nature of Semantic Information

The nature of semantic memory is complex because it captures our general knowledge about the world. Information requires a great deal of time to move from episodic to semantic memory. For example, in a study by Dagenbach, Horst, and Carr (1990), students at Millersville University did not show significant priming of newly learned words until after five weeks of practice. Thus, the conversion of knowledge from episodic to semantic memory can be a long process. That said, this process can be accelerated if new learning is done in many different contexts or settings rather than just one (Smith & Handy, 2014).

Although some theories give the impression that semantic memory has a clear structure, like a computer database, keep in mind that this is a memory system with a human face. Semantic memory certainly captures such distributional information (how often things occur), but it also captures more experiential, embodied aspects as well (Andrews, Vigliocco, & Vinson, 2009). As an example, right-handers tend to associate positive concepts with the right half of space, whereas left-handers do the opposite (Casasanto, 2009). Another embodied influence is that the retrieval of information reflects perceptual qualities (Solomon & Barsalou, 2004), such as the amount of visual area taken up by a property. For the concept *fish*, the property scales is relatively easy to retrieve, whereas the property *eye* is more difficult.

For semantic memory, when people process abstract concepts (e.g., *barrier*) they tend to rely more on associative information (what words tend to occur together), but when they are concrete concepts (e.g., *mushroom*) people rely more on similarity information (Crutch, Connell, & Warrington, 2009). That said, it may be the case that even abstract concepts have an embodied element. Concepts such as *horror* and *beauty* have an associated emotional element, and the bodily experience of the emotion may be tied, in some way, to some abstract concepts (Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011). Moreover, even simple things like how we represent nouns and verbs reflect different aspects of semantic memory. ERP recordings show that nouns, particularly concrete nouns of objects, tend to activate more of the sensory cortex (BAs 1, 2, and 3), whereas verbs of action tend to activate more of the motor cortex (BA 4) (Andres, Olivier, & Badets, 2008; Pulvermüller, Lutzenberger, & Preissl, 1999).

PHOTO 9.1 *When people access information in semantic memory, embodied influences, such as how a blender sounds, or how fruit tastes, can influence the availability of other information along that same sensory modality*

Source: moodboard/moodboard/Thinkstock

In a compelling demonstration of embodied cognition on semantic memory, Pecher, Zeelenberg, and Barsalou (2003) gave students a property identification task in which they were shown pairs of words, such as “BLENDER–loud.” The task was to indicate whether the second word was a property of the first. Students were faster when the property was from the same sensory modality as the previous trial. For example, people were faster to respond to “BLENDER–loud” if it immediately followed “LEAVES–rustling” (which also involves sound) than if it followed “CRANBERRIES–tart” (which involves the sense of taste). This suggests that semantic knowledge, although abstract in that it does not refer to specific events, is still very much influenced by how we physically interact with the world.

Stop and Review

The activation of knowledge in semantic memory causes the priming of related concepts. The more semantically related the concepts are, the more they prime each other. After an initial, automatic process, which is typically all that is involved, people may also engage in a more consciously controlled search of semantic memory as needed. Priming can extend beyond immediately related concepts to more distant concepts (albeit more weakly), as with mediated priming. Semantic memory retrieval more generally is facilitated by more connections among concepts. This is in contrast to episodic memory, in which more associations impede retrieval. Finally, semantic information, although seemingly abstract, can clearly capture embodied qualities of thought.

CATEGORIES

An important job of semantic memory is the organization of categories. Rather than remember lots of bits and pieces of information, we group knowledge together. This similarity-based grouping is **categorization**, in which two or more entities are treated as though they are equivalent. The process of categorization allows us to draw on prior experience in a regular and reliable fashion in new situations. We can assume that some of the elements of the new situation will be like those that were observed previously. For example, having the category “dog” allows a person to treat members of that category as being more or less the same, such as knowing that all dogs eat dog food, may bite, and like to run. In this section we look at various ideas of how semantic memory categorizes information. We first look at some properties of human categories, followed by some theories of categorization (Medin, 1989; Medin & Smith, 1984). After this, we look at cases of human categorization in social situations, namely stereotypes and prejudice.

Properties of Categories

Human categories are complex, with the various category members relating to a category in different ways. One way that people use categories is seen in the three **levels of categorization**: basic, subordinate, and superordinate (Rosch & Mervis, 1975). The basic level is the one at which we operate at most often. It is at this level that categories are defined by features that provide enough detail to allow us to treat different members as similar but without providing more detail than is often necessary. Examples of basic-level categories are things like saw, dog, chair, or drum. The subordinate level provides detailed information about more specific portions of a basic category. Examples of subordinate-level categories are things like camping saw, miniature poodle, leather recliner, and kettle drum. Finally, the superordinate level provides very general information that captures a wide range of basic-level categories. Examples of superordinate categories are tool, pet, furniture, and musical instrument.

This distinction between levels reflects how people use categories. In general, basic-level category information is retrieved better than the other two (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). People can retrieve more attributes for basic level categories and are able to retrieve the names of basic-level categories faster than the others (Tversky & Hemenway, 1984). This difference in retrieval speed is shown in Figure 9.2. This suggests that the basic level has some primacy in semantic memory.

Categories have many members. Their combined influence manifests itself in several ways. First, categories exhibit a **central tendency**, or averaged category ideal. This will be important when we discuss category prototypes. Second, categories have **graded membership**. Some members are thought of as being better members of the category than others. For example, *robin* is often thought of as being a better member of the category bird than *penguin* is. Alternatively, some things are ambiguous category members that may be marked with linguistic hedges—for example, statements like “technically, a tomato is a fruit” or “loosely speaking, a bat is a bird.”

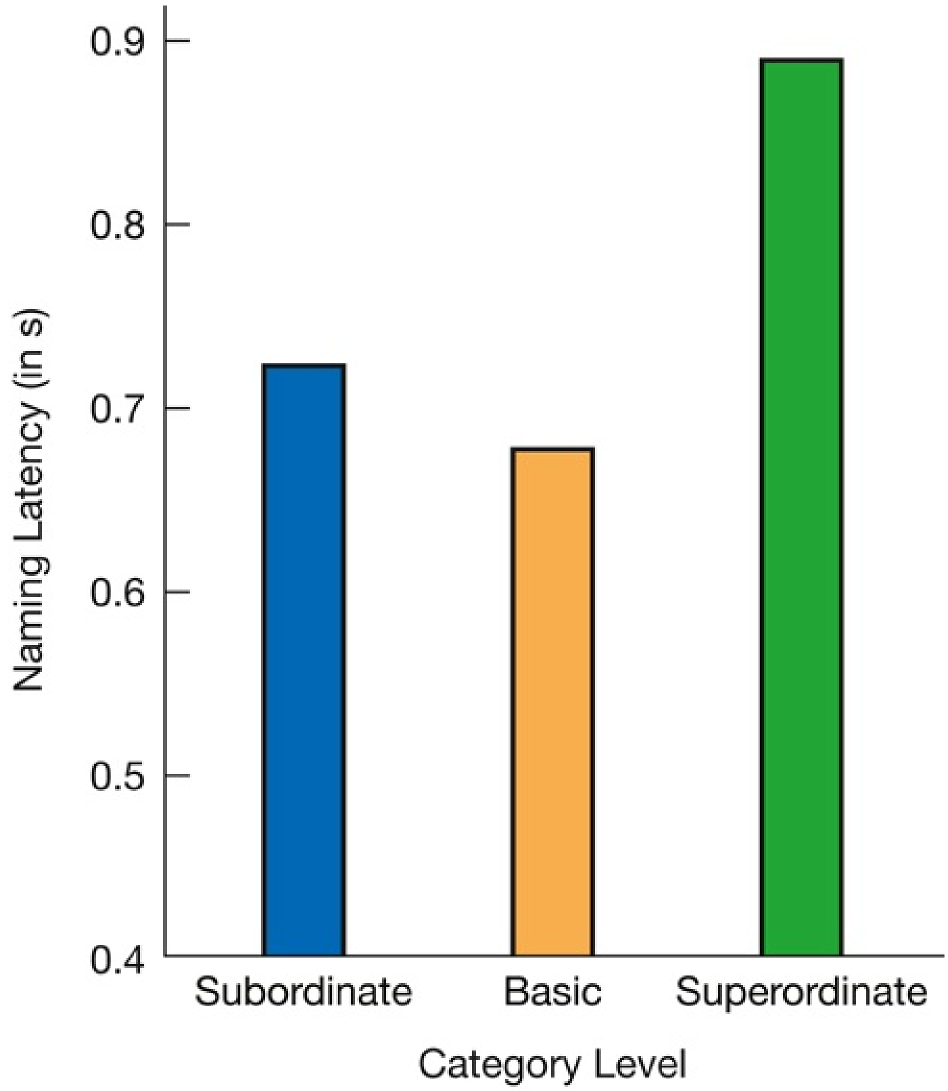

FIGURE 9.2 *Naming Time for Concepts at Different Category Levels*

Source: Tversky, B., & Hemenway, K. (1984). Objects, parts, and categories. *Journal of Experimental Psychology: General*, 113, 169–193

Finally, members of a category might not be defined by a single set of features. Different features may be shared among several category instances. This is called **family resemblance** (Rosch & Mervis, 1975). An example of this is the category *furniture*. Many types of furniture have legs, are made of wood, are intended to be used indoors, but this is not true of all types of furniture. These principles illustrate that people are sensitive to the correlations among features that define categories—for example, the idea that flying tends to go with birds and tires tend to go with bicycles. This is true in terms of both how categories are distinguished from one another and the features that create a family resemblance within categories (Chin-Parker & Ross, 2002).

One important distinction between two classes of categories is between **artifact categories** (things that people make) and **natural kind categories** (things that are found in nature). These category classes are served by different brain regions (Martin & Chao, 2001). First, like most semantic memories, the left hemisphere tends to be more involved than the right. Natural kinds, such as animals, tend to involve more of the *medial* fusiform gyrus (BA 37) and superior temporal gyrus (BA 41). In comparison, artifacts involve more of the *lateral* fusiform gyrus (BA 37) and the posterior middle temporal gyrus (BA 21), near brain regions important for verbs and action (consistent with an embodied cognition view that artifacts are understood by how we interact with them). While both classes of categories show graded membership, this is more evident in artifact categories (Estes, 2004). This is because people have more certainty about natural kinds (e.g., what makes something a bird), and have more ambiguity about artifacts (e.g., what makes something a tool). Also, people make perceptual decisions faster when comparing objects from natural kind categories (what something looks like tells you what it is) but make manipulability (how you use it) decisions faster when comparing objects from artifact categories (Kalénine & Bonthoux, 2008).

Classical Theory of Categorization

When you think of categories, you might think that people use rules to define them—for example, knowing that a *bachelor* is an unmarried adult male, that an *even number* is divisible by two, and that *speeding* is going faster than the posted limit. The idea that categories are defined by necessary and sufficient features is the **classical view of categorization**. They are *necessary* in that those features must be present and they are *sufficient* in that, as long as they are present, something is a member of a category. Any additional features are irrelevant. For instance, the number of teeth people have is additional information that has no bearing on whether they are bachelors.

A study by Bruner, Goodnow, and Austin (1956) provided support for the classical view. In this study, people were shown figures like those in Figure 9.3. Here, items can be identified along four dimensions: the type of objects, their number, their color, and the number of borders. When people are given subsets of items, along with an indication of whether each one is a member of a category, people can derive the category rules. Three category derivation examples are provided in Figures 9.4, 9.5, and 9.6.

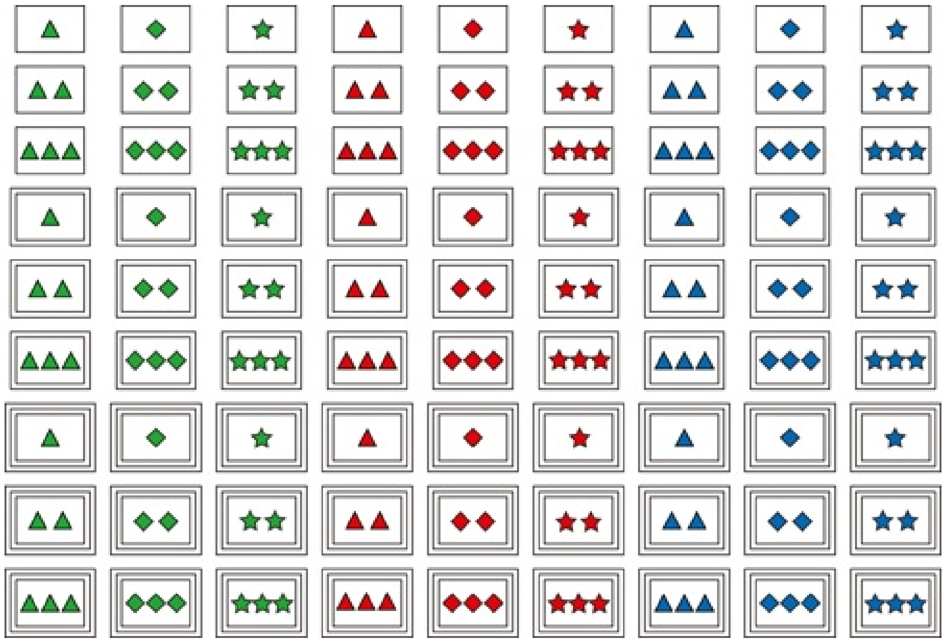

FIGURE 9.3 *Set of Stimuli Used to Illustrate the Classical View of Categorization*

Source: Bruner, J. S., Goodnow, J. J., & Austin, G. A. (1956). A study of thinking. Oxford: Wiley

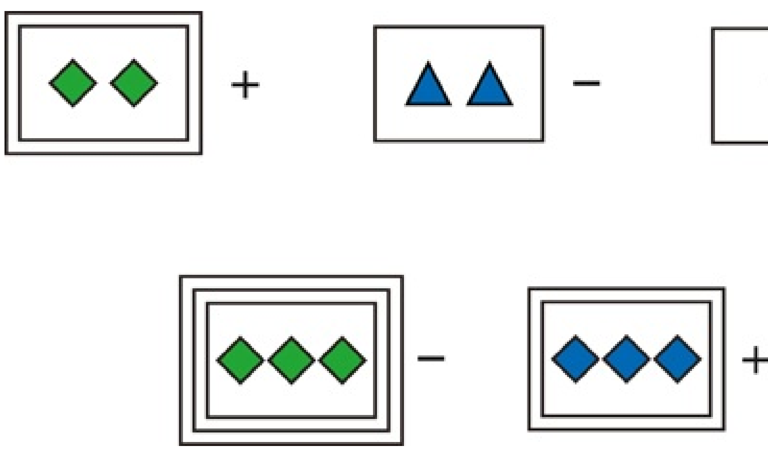

FIGURE 9.4 *Simple Set of Items Used to Derive a Category*

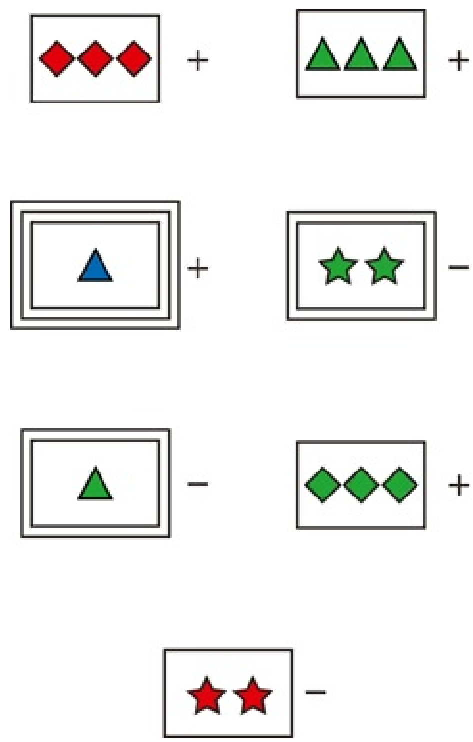

FIGURE 9.5 *Moderately Complex Set of Items Used to Derive a Category*

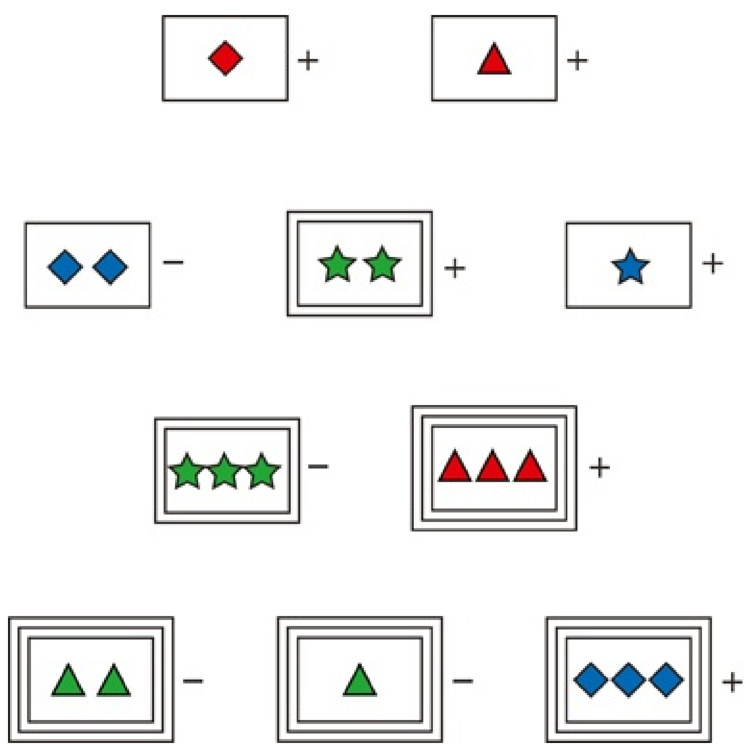

FIGURE 9.6 *More Complex Set of Items Used to Derive a Category*

That said, it does not appear that this is how humans typically derive and use categories. The classical view cannot explain central tendency, graded membership, and family resemblance. Part of this rests on the fact that the brain does not work on the either/or principles of a digital computer. Instead, it makes judgments based on loose and shifting collections of cell assemblies, giving the judgments it produces a fuzzier quality (Lupyan, 2013). It is also important to keep in mind that the elements, features, or properties that define category members can vary in their importance (Ashcraft, 1978). Some are going to be more important in defining a category than others. More specifically, rarer features are more diagnostic than common features in defining a category (Mirman & Magnuson, 2009). For example, "has a trunk" is more defining of an elephant than is "breathes," although both are needed.

The shortfall of the classically view of categories as a description of categories in semantic memory is also clearly seen when one looks at categories that have simple and clearly defined rules, such as the categories *even number* and *odd number*. However, they show graded membership (Armstrong, Gleitman, & Gleitman, 1983). In the data shown in Table 9.1, "4" is rated as a better example of the category *even number* than "106" is, even though they are both equally acceptable members of this category. In a similar study by Lupyan (2013), people were more willing to call equilateral triangles "triangles" compared to right, scalene, and isosceles triangles, even though they are all *triangles*. Similarly, people were more willing to call a woman a "grandmother" the older that woman was and the more grandchildren she had. Moreover, some people were also willing to call a woman a "grandmother" if she was old and had children but no grandchildren. There were even some people who were willing to call someone a "grandmother" if that person had several children and grandchildren and was a man! So, the big message here is that we play more fast and loose with our mental categories than we sometimes might want to admit.

TABLE 9.1 *Ratings of Items (Out of 6) for a Well-Defined Category—in this Case, Odd and Even Numbers*

Even Number	Rating	Odd Number	Rating
4	5.9	3	5.4
8	5.5	7	5.1
10	5.3	23	4.6
18	4.4	57	4.4
34	3.6	501	3.5
106	3.1	447	3.3

Adapted from: Armstrong, Gleitman, & Gleitman (1983)

Prototype Theory

Categories are organized, in part, using unconscious mental statistics. One idea of how this is done is the **prototype model**. For this view, categories are determined by a mental representation that is an average of all category members. This averaged representation is a *prototype* (Rosch, 1975), which may or may not correspond to an actual entity in the world. For example, the prototype for *dog* would be an average of all dogs ever encountered, and may not correspond to any particular kind of dog.

An example of prototype extraction using dot patterns is shown in Figure 9.7. The prototypes for the two categories are shown at the left. When people first learned the categories, they were shown deviations from the prototypes, such as those on the right. The prototypes were never shown during learning. However, when people were later asked to sort both old and new patterns the prototypes were identified and correctly sorted at a high rate of accuracy, suggesting that they were derived and used to make decisions (Posner & Keele, 1968, 1970). If people can readily derive prototypes from things as meaningless as dot patterns, surely the same mental mechanisms are involved for deriving categories of our everyday experiences with everyday objects.

This use of prototypes is also seen with meaningful stimuli. For example, if photographs of faces are used for making preference judgments along with morphed composites of faces, people rate the composite faces, which are closer to the prototype face, as more attractive (Langlois & Roggman, 1990; but see Alley & Cunningham, 1991). That is, people prefer faces that are averages of others. Because they are averages, they have fewer unusual and distinguishing characteristics and so are easier to mentally process (Winkielman, Halberstadt, Fazendeiro, & Catty, 2006). A pretty face is a boring face. This is also part of the reason why attractive faces are harder to remember (Light, Hollander, & Kayra-Stuart, 1981). High attractiveness for more prototypical instances is also observed for dogs, cats, birds, fish, watches, and automobiles (Halberstadt & Rhodes, 2000, 2003).

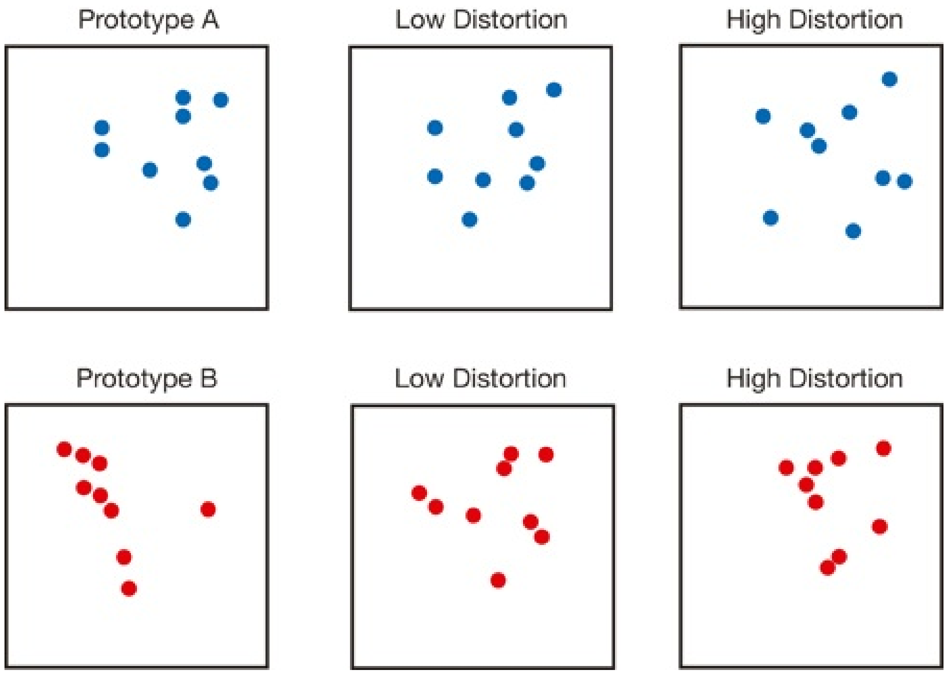

FIGURE 9.7 *Two Category Prototypes and Some Distortions*

The nice thing about prototypes is that they provide a clear explanation for the central tendencies of categories (which is the prototype itself) and a graded category structure. The closer an instance is to the prototype, the better a member of the category it is. However, there are important aspects not accounted for. For example, people are often aware of a category size —that is, about how many different members are in the category. For example, we know that *insect types* is a large category, but *elephant types* is a small one. Prototypes convey no information about the variability among category members. Also, a caricature (a category member with exaggerated features) is thought to better represent a category than a prototype when a category is considered in the context of other, related categories (Goldstone, Steyvers, & Rogosky, 2003). That is because the caricature captures distinctive features and emphasizes them. This helps distinguish one category from other, similar categories.

Exemplar Theory

Another approach to categorization is **exemplar theory** (Medin & Schaffer, 1978; Nosofsky, 1988). In this view, people use all the category members to make decisions. This captures central tendency, graded membership, and family resemblance, as well as information about category size, variability, correlated attributes, and any new information about the category. Because categorization is always using all of the memory traces, new experiences can have an influence.

Another advantage of exemplar theories is that they can explain the context sensitivity of categories. For example, the color gray is more similar to white in the context of hair color but is more similar to black in the context of clouds (Medin & Shoben, 1988). Finally, previously activated semantic meanings can bias how new information is interpreted (Gagne & Shoben, 2002). For example, a phrase like "adolescent doctor" is easier to interpret if it follows the phrase "animal doctor" than if it follows "country doctor." In this case, both "adolescent doctor" and "animal doctor" refer to the kind of patient the doctor treats, whereas "country doctor" refers to where the doctor lives.

In terms of whether people use prototypes, or more exemplar-based processes, to define their categories, it seems that both are used, though in different circumstances. Specifically, it is more adaptive in a natural environment to move early on from a more exemplar-based form of categorization to a more prototype based form of categorization. This allows people to deal with the family resemblance of many natural kinds and be less led astray by more peripheral and irrelevant features of individual category members (Smith, 2014).

A serious problem with both prototype and exemplar theories is an inherent circularity. Specifically, categories are defined by experiences with members of that category. That is, the members of the category all contribute to defining it. However, the memory traces that are selected are those that conform to the criteria of the category. In short, how can memory traces be selected to define a category if the cate gory is needed to select them in the first place?

TRY IT OUT

Here is a study that can illustrate the influence of human categories on thought (see Neath, 1998). For this task, you need to use this list of eight animals: goose, duck, robin, sparrow, hawk, eagle, ostrich, and bat. This will serve as a basis for people making categorical judgments.

To do this project, you will need 36 people in six groups. Give people this list of animal names, preferably in a different random order for each person. Tell your participants to assume that these animals live in close proximity to one another, such as on an island. Then ask people to estimate how many animals of the other species are infected given that a particular animal has a certain disease. Tell each group that the infected species is either the goose, duck, robin, sparrow, hawk, or eagle (leave out ostrich and bat), depending on the group, and have them estimate what percentage of the other animals is likely to be infected as well.

After people have made their estimates, gather the data together and calculate the average estimates for each of the different infected species. What you should find is that the more typical the infected animal is of the category bird, the higher the percentage of other animals infected, and the less typical the animal, the lower the percentage.

Explanation-Based Theory

Another view of categorization is that people try to have reasons for why things should be grouped together. For **explanation-based views**, categories are theories or explanations. For example, feathers and wings tend to go together because feathers are suited for flying. People seek out and use their knowledge to understand how the members of a category form a coherent group (Rehder & Ross, 2001). Examples of this are social groups, political events (e.g., revolutions), and social institutions (e.g., governments). These do not share physical features but overlap thematically.

In general, people place an emphasis on causal factors as compared to the effects (Ahn, Kim, Lassaline, & Dennis, 2000), which is consistent with the idea that they are creating explanations for what makes something a category. For example, knowing that an animal swims is a more fundamental characteristic than knowing that an animal has webbed feet (presumably they have webbed feet because they swim). Also, categories are defined, in part, by how people interact with things (Markman & Ross, 2003), not just statistical regularities. For example, what makes something a chair has more to do with your sitting in it than with the materials used to make it. This is because chairs are made of different types of materials. Causal relations help define semantic memories (Fenker, Waldmann, & Holyoak, 2005).

Another important point is that people can make new categories on the fly. These are **ad hoc categories** (Barsalou, 1983). For example, coffee, perfume, leather, and skunks are all members of the category *things with a distinctive smell*. Ad hoc categories are interesting because people generate them off the cuff but they have many of the same properties as standard categories. They have a central tendency, graded structures, and family resemblance. Thus, some semantic memory structures are generated spontaneously. This raises questions about the stability of semantic memory in general.

Consistent with the idea that we create categories in the pursuit of explanations is **psychological essentialism**. This is the idea that members of a category share an underlying essence, of which people may or may not be aware. This usually applies to natural kind categories, which can be defined by chemical structure or DNA, such as water or *skunk*. That said, some artifact categories, such as *scientific instruments*, are treated as though they have essential qualities, and some natural kind categories, such as *humans*, are not (Kalish, 2002). People create categories pragmatically, as is needed, to serve a purpose. The degree to which members fit a category is a function of how well they fulfill that purpose.

Stereotypes and Prejudice

There is no question that categorization, on the whole, is a valuable part of semantic memory. However, it can cause problems, such as when we engage in stereotyping. Stereotypes are categories for groups of people. When you stereotype people, you are treating them as if they are essentially the same as other members of that group. These stereotypes are activated automatically (Oakhill, Garnham, & Reynolds, 2005). We use this semantic knowledge to make assumptions about people and are surprised when those assumptions are violated (Duffy & Keir, 2004). When a stereotype leads one person to treat another inappropriately, this is prejudice. So, while categories are generally useful, we must be careful with the categories we form about people.

Stop and Review

A central job of semantic memory is to create categories. People’s categories are oriented around a basic level and show evidence of central tendency and graded membership, with family resemblance among the members. Human categorization typically does not follow the necessary and sufficient rules of classical categorization. Instead, it uses probabilistic information, as in prototype and exemplar theories. Moreover, it also exhibits characteristics of people problem solving their way to category creation, as with the use of explanation-based categories. Overall, human categorization reflects both environmental (probabilistic theories) and goal-oriented (explanation-based theories) influences (Love, 2005; Rouder & Ratcliff, 2006).

ORDERED RELATIONS

Another characteristic of semantic memory is the influence of knowledge that is ordered along some dimension, such as size, intelligence, or age. These are linear order effects (Banks, 1977) and reflect the organization of information as it is stored or processed in semantic memory. We first cover some of the classic order relations effects and then go over some embodied influences on how we think about ordered relations.

Classic Ordering Effects

One ordering effect is the **semantic distance effect**, in which people make faster judgments about the order of two items as the distance between them increases (Rips, Shoben, & Smith, 1973). For example, it is easier to judge that an elephant is bigger than a rabbit than to judge that a dog is bigger than a rabbit. The farther two concepts are along a dimension, the easier it is to discriminate between them and, so, people process this information quickly. As another example, people are more likely to confuse adjacent days of the week rather than days that are separated from one another (Ellis, Wiseman, & Jenkins, 2015). As an embodied illustration, people find it easier to make memory responses on a computer keyboard if the response keys are far from one another, such as "A" and "L," than if they are adjacent, such as "K" and "L" (Lakens, Schneider, Jostmann, & Schubert, 2011). Concepts that are close in semantic memory are harder to discriminate, so judgments that require people to distinguish between them are slower and more prone to error.

For the **semantic congruity effect**, people are faster to judge the relationship between two items if the valence of the comparison term matches the end of the dimension they are on (Banks, Clark, & Lucy, 1975). For example, it is easier to judge that Jefferson was president before Monroe than it is to judge that Monroe was president *after* Jefferson because both are at the "early" end of the dimension. Dimensional information is stored in semantic memory along with the concepts. Jefferson and Monroe are both thought of as early U.S. presidents, so the attribute "early" is stored directly with them. When this information is needed, if the attributes match the judgment people respond faster than if there is a mismatch. With a mismatch, people need to do more thinking to get the information lined up properly.

PHOTO 9.2 *When we judge information that is stored in semantic memory that varies along a dimension, such as size, the relative sizes of the items can influence the ease with which those semantic judgments are made*

Source: GlobalP/iStock/Thinkstock

Finally, for the **serial position effect**, people are faster to make judgments about two or more items at the extremes of a dimension than those in the middle (Shoben, Čech, Schwanenflugel, & Sailor, 1989). For example, it is easier to judge that Rhode Island is smaller than Connecticut than to judge that Indiana is smaller than Ohio. Items that are at the ends of a dimension are more distinct and, so, are easier to discriminate, and semantic decisions can be made quickly.

More generally, serial position effects, like those observed in short-term memory (see Chapter 4), such as the primacy and recency effects, are also observed in semantic memory. Examples of this would be memories for U.S. presidents (Roediger & Crowder, 1976) and church hymns (Maylor, 2002). These serial position curves are due to the frequency of exposure to information, with people encountering the names of the very early and recent presidents more than others (Healy, Havas, & Parker, 2000). This also accounts for the fact that Lincoln is remembered much better than he should be based on serial position.

Embodied Influences on Ordered Relations

How we use our bodies to interact with the world can influence semantic order knowledge. One example of this is the spatial-numerical association of response codes, or **SNARC effect** (Dehaene, Bossini, & Giraux, 1993). When people made judgments about numbers, such as whether they were odd or even, judgments about smaller numbers were made faster with the left hand. The reverse was true for the larger numbers. The SNARC effect is consistent with the idea that people have a mental number line in semantic memory going from left to right with small numbers on the left and large numbers appearing as one moves to the right (but see Santens & Gevers, 2008), although this may be due to relative, rather than absolute, magnitudes (Nathan, Shaki, Salti, & Algom, 2009).

The SNARC effect reflects perceptual experience in that it is more prominent in people who speak languages that are read left to right rather than right to left (Dehaene et al., 1993; Shaki & Fischer, 2008). However, it is also observed in blind people (Castronovo & Seron, 2007), suggesting that it is not strictly visual. Moreover, the SNARC effect is not limited to numbers. Lidji, Kolinsky, Lochy, and Morais (2007) found a similar pattern with musical pitches. People respond faster to lower tones with the left hand and higher tones with the right, similar to the arrangement of notes on a piano or guitar string.[1]

Another example of embodied influences on semantic memory is that people are faster to identify words that refer to large objects (e.g., bookcase) than to small objects (e.g., teaspoon) (Sereno, O'Donnell, & Sereno, 2009). Furthermore, the closer an object is to a person, in terms of space, time, or social relations, the more effectively it is processed. Although knowledge of an object could be abstract, it turns out that the more likely we are to interact with it, the more accessible it is in memory (Amit, Algom, & Trope, 2009). So, people incorporate embodied processing in abstract conceptual knowledge.

Stop and Review

Semantic memories capture ordered relations in the world, with the availability of knowledge being influenced by relative positions in an order. The classical ser ial ordering effects are the semantic distance, the semantic congruity, and the serial order effects. In addition, ordered information can show embodied influences, based on how we interact with things in the world, as exemplified by the SNARC effect.

SCHEMAS AND SCRIPTS

In life, there are many situations that are fairly regular in how they unfold and operate, and how we react to them. That is, common experiences shared some framework that unites them. We are able to capitalize on this to help us understand new situations, much as we use categories to understand new objects or creatures. A semantic memory that captures commonly encountered aspects of life is called a **schema**. This was an idea originally developed by Bartlett (1932).[2] Schemas contain the basic information about the components of a certain aspect of life and how these parts interact with one another. A schema can be thought of as a blueprint for events that people can draw upon to understand a specific case. In some sense, schemas are types of theory-based categories. As you will see, schemas can be used to help memory, but they can also hurt memory.

Primary Schema Processes

There are five primary schema processes (Alba & Hasher, 1983). These are selection, abstraction, interpretation, integration, and reconstruction. The first four are for the encoding of new information, and the fifth is important during retrieval.

If people have a schema, they can use the process of **selection** to sort out which things are likely to be central and which are peripheral. That is, schemas select out those elements that are important. For example, when watching a football game, it is important to understand how much time has elapsed. Your schema for football tells you to pay attention to the clock. In contrast, if you were watching a baseball game, the amount of time that has elapsed is of considerably less importance. Thus, your schema for baseball would select out information about the time. Information that is important in schemas is more likely to be encoded and remembered.

Knowing which schema is relevant can greatly influence performance. For example, in a study by Bransford and Johnson (1972), people read an ambiguous passage (see Table 9.2). If people are told ahead of time that the passage is entitled "Washing Clothes," then they remember more of it later. The title allows them to activate the appropriate schema and they can then select what is relevant in the passage and interpret it. This occurs during encoding because this title benefit is only observed when it is given *before* reading (Summers, Horton, & Diehl, 1985).

Abstraction involves converting the surface form of information (e.g., verbatim wording) into a more abstract representation that captures the underlying meaning (Burgoon, Henderson, & Markman, 2013). For example, when people hear sentences and comprehend them, within a few minutes they are not be able to distinguish verbatim sentences from paraphrases (Sachs, 1967, 1974). Similarly, if people see a picture, they are less likely to notice a change, such as adding or subtracting elements, rearranging entities in the scene, or changing the orientation of entities in the picture, if the rearranged picture fits their abstract, schematic memory of what they saw (Mandler & Ritchey, 1977).

This effect of schemas is not always in the direction of making things more general. Sometimes it can be the opposite if people go from a superordinate to a basic-level category (Pansky & Koriat, 2004). For example, if one person hears "vehicle" (superordinate) and another hears "sports car" (subordinate), both will abstract this information to the basic level, "car." Keep in mind that people are likely to notice changes that alter the meaning of what they saw or heard.

An example of abstraction is shown in Figure 9.8. In a study by Carmichael, Hogan, and Walter (1932), people saw the line drawings in the middle column with one of two labels. Each of these labels is placed next to the drawing. After a period of time, people were asked to draw what they remembered seeing. Examples of the types of drawings that were produced are on the right and left sides of Figure 9.8. People tended to distort their drawings to conform to the label that was provided. People used their schemas to abstract away and lose the ambiguous information. Thus, what is remembered is more schema-consistent.

TABLE 9.2 *Ambiguous Passage that is Clarified by Activating the Appropriate Schema*

The procedure is actually quite simple. First arrange items into different groups. Of course one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to a lack of facilities, that is the next step; otherwise, you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this may not seem important, but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to necessity for this task in the immediate future, but then, one never can tell. After the procedure is completed one arranges the material into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is part of life.

Source: Bransford & Johnson (1972)

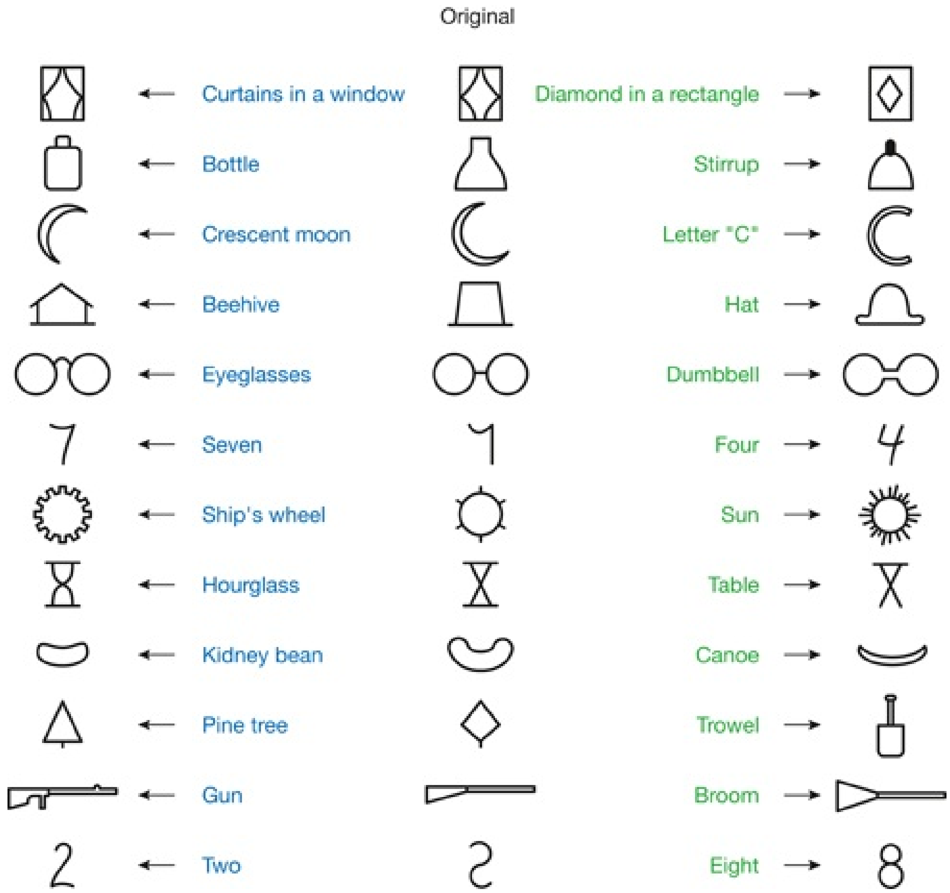

FIGURE 9.8 *Ambiguous Line Drawings in the Middle Were Given One of Two Labels. Later Reproductions by People, on the Left and Right, Conform to the Schema Activated by the Label*

Source: Carmichael, L., Hogan, H. P., & Walter, A. A. (1932). An experimental study of the effect of language on the reproductions of visually perceived forms. Journal of Experimental Psychology, 15, 73–86

The schema process of **interpretation** allows people to fill in the gaps for things that were missed. When we read a book, watch television, or even experience events, there is a lot that we miss. For example, when you see a movie, many things happen off camera. Still, you have no troubling inferring what they are. If you watch a film in which a person is boarding an airplane one moment and getting off the next, you don't think that the person got onto the plane and then immediately turned around and got off. Instead, you infer that there was a flight in between, although only a few seconds have elapsed in the theater.

Interpretation can have a powerful effect on memory. People may misremember having encountered things that they only inferred using a schema. For example, people who view a sequence of events in which they see an effect or outcome are likely to claim to remember seeing a schema-consistent cause, even if was never presented (Hannigan & Reinitz, 2001). For example, people who saw a picture of a person pulling an orange out from the bottom of a pile (cause) are less likely to misremember seeing the pile fall (effect), but people who saw a picture of the oranges on the floor (effect) are more likely to misremember seeing a person pulling an orange out of the bottom of the pile (cause).

In life we are usually get the information about an event all at once. However, sometimes we come across event descriptions that are given out piecemeal, and we need the schema process of **integration** to guide us in putting these pieces together into a coherent whole. For example, when reading a mystery novel, the author may give different aspects of the murder at different points in the story. If the reader has any hope of figuring out what happened and who the guilty party is before being spoon-fed this information at the end, these pieces of information must be integrated into a common mental representation of the event. This is done using schemas.

Up to now, we have seen how schemas influence encoding. However, schemas can also affect retrieval. Memories are not complete records of the past. Instead, they are fragmentary. Only bits and pieces of the original experience make it into consciousness. Sometimes there are a lot of fragments, enough to recover almost the entire memory, whereas in other cases the fragments are few and far between. In such cases, some **reconstruction** is needed. With reconstruction, people fill in the memory gaps. This is like a paleontologist reconstructing an entire creature from fossilized bits and pieces.

Some evidence for reconstruction comes from Bartlett's (1932) work. In one set of experiments, he gave British Cambridge University students a Native American folktale to read, called "The War of the Ghosts." This tale is shown in Table 9.3. Sometime after reading—often several days, weeks, or months later—people were asked to recall the tale. People not only forgot parts of the story but they added new elements. Often this new information was less consistent with the original story but more consistent with typical English folktales. One recall is shown in Table 9.4. Schema-based reconstruction is reflected in the idea that if the warrior had been shot he would have fallen unconscious and been carried off the battlefield. However, this was not in the original story.

People also show schematic reconstruction with nonverbal information. In one study by Brewer and Treyens (1981), students at the University of Illinois at Urbana–Champaign were asked to wait in a graduate student's office before the experiment began. However, what they did not realize was that the experiment had already begun. After spending a few minutes in the "office," they were taken to another room, where their memory for the "office" was tested. What was found was that people tended to misremember items as being in the "office" when they were not. These were articles that were consistent with an office schema. For example, many people remembered seeing books when there were none. In general, consistent with fuzzy trace theory, people use a combination of detailed memories and schemas to remember. Forgetting leads people to make judgments based on schemas rather than memories of particular instances (Gilovich, 1981). Memory reports become more schematic over time.

TABLE 9.3 *"The War of the Ghosts," a Native American Folktale*

One night two young men from Egulac went down to the river to hunt seals, and while they were there it became foggy and calm. Then they heard war-cries, and they thought: "Maybe this is a war party." They escaped to the shore, and hid behind a log. Now canoes came up, and they heard the noise of paddles, and saw one canoe coming up to them. There were five men in the canoe, and they said:

"What do you think? We wish to take you along. We are going up the river to make war on the people."

One of the young men said: "I have no arrows."

"Arrows are in the canoe," they said.

"I will not go along. I might be killed. My relatives do not know where I have gone. But you," he said turning to the other, "may go with them."

So one of the young men went, but the other returned home.

And the warriors went on up the river to a town on the other side of Kalama. The people came down to the water, and they began to fight, and many were killed. But presently the young man heard one of the warriors say: "Quick, let us go home: that Indian has been hit." Now he thought: "Oh, they are ghosts." He did not feel sick, but they said he had been shot.

So the canoes went back to Egulac, and the young man went ashore to his house, and made a fire. And he told everybody and said: "Behold I accompanied the ghosts, and we went to fight. Many of our fellows were killed, and many of those who attacked us were killed. They said I was hit, and I did not feel sick."

He told it all, and then he became quiet. When the sun rose he fell down. Something black came out of his mouth. His face became contorted. The people jumped up and cried.

He was dead.

Source: Bartlett (1932)

TABLE 9.4 *Recall Attempt for "The War of the Ghosts" Four Months Later*

There were two men in a boat, sailing toward an island. When they approached the island, some natives came running toward them, and informed them that there was fighting going on the island, and invited them to join. One said to the other, “You had better go. I cannot very well, because I have relatives expecting me, and they will not know what has happened to me. But you have no one expecting you.” So one accompanied the natives, but the other returned.

Here there is a part I can’t remember. What I don’t know is how the man got to the fight. However, anyhow the man was in the midst of the fighting, and was wounded. The natives endeavored to persuade the man to return, but he assured them that he had not been wounded.

I have an idea that his fighting won the admiration of the natives.

The wounded man ultimately fell unconscious. He was taken from the fighting by the natives.

Then, I think it is, the natives described what happened, and they seem to have imagined seeing a ghost coming out of his mouth. Really it was a kind of materialization of his breath. I know this phrase was not in the story, but that is the idea I have. Ultimately the man dies at dawn the next day.

Source: Bartlett (1932)

TRY IT OUT

Here is a study that can illustrate the influence of whether schemas are used or not (Zechmeister & Nyberg, 1982). You will need two passages. One should be the “Washing Clothes” passage in Table 9.2. The other is one about running a pizza parlor and is listed below.

You should have at least 12 people for this study. For each person, read them one of the passages with the title and the other without. If you test people individually, try to counterbalance the order in which people get the passages and the order in which they either do or do not get the titles. After reading each passage, have people write down as much as they can remember.

After people are done recalling, score their recalls for how many basic ideas from the passages appear in their reports. What you should find is that people remember more from the passage for which you provided the title. The title activates the appropriate schema, making it easier to remember.

“Generally the atmosphere is not conducive to street clothing. Proper attire lessens the worry. It may also facilitate dexterity. Awe-filled spectators surely provide extra motivation. Hopefully they don't cause distractions. Finesse and enthusiasm add a lot to the performance; however, the final results constitute the true measure of achievement. Experiment with ways of throwing. Making the thick pellets into thin skins is the aim. You usually cannot select all the constituents. Customers choose much themselves. Your task is to integrate the raw material. Careful engineering of embellishment placement guarantees consistency of quality. Once heated, no changes can be made. Consumption is imminent. Quantity ultimately secures survival."

Scripts

When knowledge refers to a sequence of events that occurs in a stereotyped fashion, this is a special type of schema. These **scripts** are temporally ordered schemas that are structured according to the major components of the event (Abbott, Black, & Smith, 1985), with a preference for using script information in a forward order (Haberlandt & Bingham, 1984), although more central components may be more available (Galambos & Rips, 1982). People have good memories for the order of events for common aspects of life. When people are asked to list the components of a script, such as what happens at a restaurant, many of the lists have the same entries (Bower, Black, & Turner, 1979), suggesting that there is a great deal of regularity captured by this type of semantic memory. A typical list for what to do in a restaurant is shown in Figure 9.9.

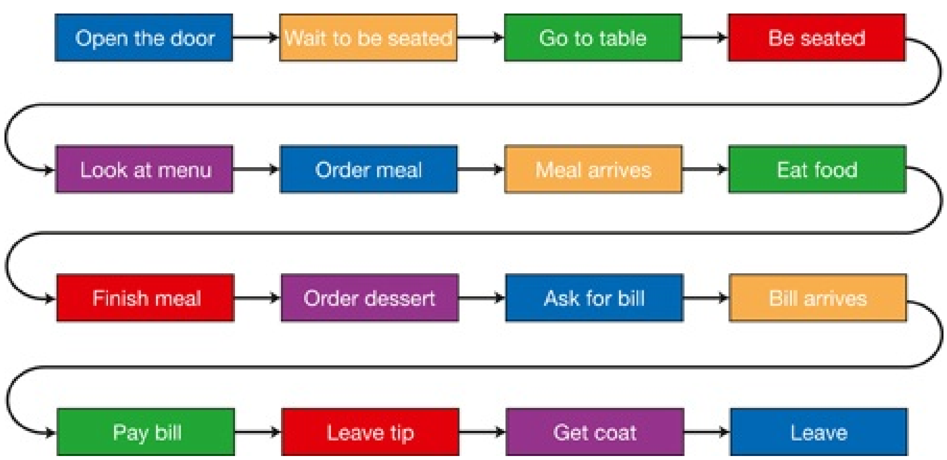

FIGURE 9.9 *Example of a Script for What to Do at a Restaurant*

Adapted from: Bower, G. H., Black, J. B., & Turner, T. J. (1979). Scripts in memory for text. *Cognitive Psychology*, *11*, 117–220

The use of scripts influences how information is retrieved and used. For example, when people read a text of a scripted event they take longer to read a sentence when the action is further along in the script from the prior sentence than if it is closer (Bower et al., 1979). For a story about going to a restaurant, if people had just read a sentence about waiting to be seated, they would read the next sentence faster if it was about looking at the menu than if it was about finishing the meal. People are scanning their scripts to help make sense of what they are reading. When the information is close in the script, less effort is required. However, when the information is far in the script, more effort is required because more of the script needs to be scanned to bring the person up to date. More knowledge must be inferred.

The influence of scripts is also seen when people are given information about a scripted event in a random order. During later recall, there is a tendency to report those fragments in an order that more closely approximates the script (Bower et al., 1979). Moreover, if people provide summaries of normal and scrambled texts, their summaries are similar (Kintsch, Mandel, & Kozminsky, 1977). Thus, people use scripts to organize information to help them both understand it and remember it better.

Limits on Schema Usage

While schemas and scripts have a large influence on memory, they are not always used. For example, people are likely to make causal inferences because understanding causal relations is important for understanding how the world is structured and operates. However, when given partial information about a cause and effect sequence, people do not always make these inferences. There is a bias to infer causes but not effects because people can easily infer how they may have gotten to a current point in time (what caused this) if they access the appropriate schema. However, knowing what will happen next (what effects to predict) is more difficult because in many cases any number of possible outcomes could exist. This is not to say that people never use schemas to make predictions about the future—only that they are much less likely to do so.

It is also possible to get people to disregard schema-generated information when the schema has been discredited. This was done in a study by Hasher and Griffin (1978; see also Anderson & Pichert, 1978), where students were given ambiguous texts, such as the one in Table 9.5. It is ambiguous because it could be either about an escaped convict or a deer hunter. Students were first asked to read this text from one perspective. After a brief delay, the students were asked to recall the story. Some did this from the same perspective as they read it. In contrast, others were led to believe that the experimenter had given them the wrong title initially. They were then given the "correct" other title. The results are shown in Table 9.6. When there was a title switch, people recalled the same amount of information as when there was no switch. However, there were important differences. When there was a title switch, people made fewer intrusions, whereas those who did not have the switch made a large number of schema-consistent intrusions. Thus, people can disregard schemas and use more detailed, verbatim memories.

TABLE 9.5 *Ambiguous Story Consistent with Two Schemas—an Escaped Convict or a Deer Hunter*

The man walked carefully through the forest. Several times he looked over his shoulder and scrutinized the woods behind him. He trod carefully, trying to avoid snapping twigs and small branches that lay in his path, for he did not want to create excess noise. The chirping of the birds in the trees almost annoyed him, their loud calls serving to distract him. He did not want to confuse those sounds with the type he was listening for.

Source: Hasher & Griffin (1976)

TABLE 9.6 *Influence of a Schema Shift on Later Memory for Schema Consistent Inferences. The data is for the percentage of idea units recalled from an ambiguous story and the number of intrusions based on the initial theme, the alternate theme, or some other theme*

Condition	Idea Units	First Theme	Second Theme	Neutral
Same schema	35%	2.58	0.17	0.92
Schema shift	35%	0.54	0.08	1.33

Source: Hasher & Griffin (1976)

Improving Your Memory

Semantic memory is our knowledge of the world. It is what we draw upon when we are trying to learn and understand new things. Semantic memory can help learning. When you encounter new materials in your classes or at work, it is very rare that what you will be learning bears almost no relation to what you already know. There is going to be some overlap. If you can activate or prime this knowledge prior to learning, this will help you better encode the new material. There are lots of ways to do this. Prior to reading a textbook, you can scan a chapter or section to see what the section titles are, and if they are any terms in bold. This can activate the knowledge in semantic memory that will help you structure the new information. Also, to get more out of a lecture, read the syllabus to see what topics will be relevant that day. Reading the book ahead of class also provides semantic knowledge that will increase the amount of new material you will learn during lecture (which you will hear only once).

Stop and Review

Semantic memories for commonly experienced aspects of life are schemas. During learning, schemas can be used in a number of ways. They can select out those aspects of an event that are more relevant and important, abstract away the critical ideas, help draw inferences through a process of interpretation, allow missing information and gaps to be filled, and facilitate the integration of otherwise separate bits of information into a single coherent memory. During retrieval, schemas can help reconstruct details that were forgotten. For standard sequences of events, people can use specialized schemas called scripts. These provide a guide for people to know what the correct order of events should be. While schemas and scripts have powerful influences on memory, they do not always dominate. In the right circumstances people can disregard their schemas and scripts and more accurately remember the details that were actually encountered.

PROBLEMS WITH SEMANTIC MEMORY

Semantic memories capture regularities about the world, and so they are useful in predicting new situations. Semantic memories are reasonably accurate, as far they go. That said, they are not perfect. They can sometimes lead us to make errors. In this section we discuss two types of errors. These are semantic illusions and the errors that can accompany naïve physics.

Semantic Illusions

How many animals of each kind did Moses take on the ark? Many people respond with the answer “two,” but this is incorrect. Moses did not take any animals on the ark; Noah did. In the original study of this memory error, Erickson and Mattson (1981) found that 81% of students at the University of California, San Diego, responded with the answer “two” even though they all knew the correct answer. Thus, this semantic memory error is called the **Moses Illusion**. So, why do so many people make this mistake? Semantic memory, like other types of memory, is prone to error. In addition to general forgetting, errors can involve the inappropriate retrieval of information.

This illusion does not appear to be due to people mentally correcting the question or making rushed responses (Reder & Kusbit, 1991). It also occurs when there is overlapping lexical information, such as a similar name, for example when people give an inappropriate response to the question “What was the famous line uttered by Louis Armstrong when he first set foot on the moon?” (Büttner, 2007; Shafto & MacKay, 2000).

There are three accounts of the Moses Illusion. First, semantic processing is very general unless people focus on the information of interest (Erickson & Mattson, 1981). That is, we only do a cursory check of knowledge in semantic memory to see if the information is broadly consistent. Second, people engage in only a partial assessment of semantic information (Reder & Kusbit, 1991). That is, people retrieve some of the information from semantic memory and, so long as it is a close fit, they are willing to go with it. Third, similar language elements, such as a similar name, can inappropriately activate information in semantic memory, giving the illusion that it is known (Shafto & MacKay, 2000). In other words, if it sounds close, people are often willing to disregard some smaller inconsistencies. Thus, information in semantic memory is accessed in an imprecise way and can lead to errors.

Naïve Physics

Semantic memory illusions also apply to nonverbal knowledge. As was discussed in Chapter 5, memory can incorporate physical principles of the world, such as gravity and friction. Some **naïve physics** knowledge is stored in semantic memory. However, when we consciously try to apply this knowledge, misunderstandings can be revealed. In some studies, students at Johns Hopkins University were given diagrams such as those shown in Figure 9.10. The task was to indicate (1) the trajectory of a ball shot out of the tube, (2) the trajectory of the ball when the string broke, and (3) the path of the bomb when the plane dropped it. The responses are shown in Figure 9.11.

Although people do give the correct responses in some cases, they also give incorrect responses using incorrect knowledge in semantic memory (McCloskey, Caramazza, & Green, 1980). What is interesting is that people are responding as if they are holding medieval impetus theories of motion (but see Cooke & Breedin, 1994). Such responses are more likely when people use static diagrams and are less likely when viewing moving displays (Kaiser, Proffitt, & Anderson, 1985; McCloskey & Kohl, 1983), although not always (Rohrer, 2003).

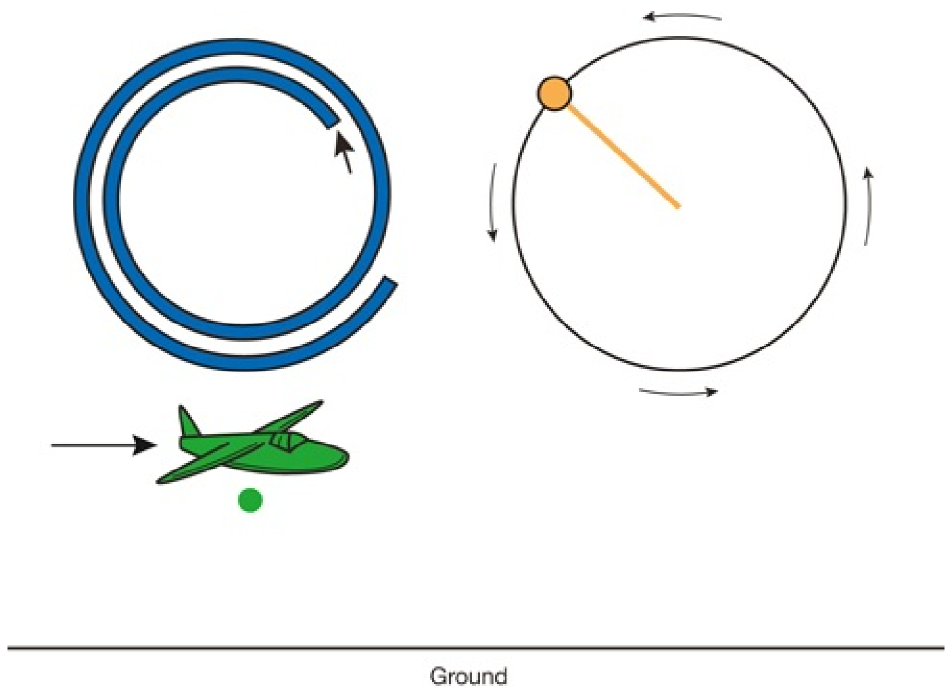

FIGURE 9.10 *Stimuli Used to Illustrate Principles of Naïve Physics: a Person's Task is to Show the Path of the Ball Once It Leaves the Tube or Is Released*

Source: McCloskey, M. (1983). Naïve theories of motion. In D. Gentner & A. L. Stevens (Eds.), *Mental models* (pp. 299–324). Hillsdale, NJ: Erlbaum

With education, people can overcome their naïve beliefs about motion. That said, these beliefs never seem to go away completely. For example, if people are asked to verify statements that are inconsistent with early childhood beliefs, such as the idea that the earth goes around the sun, people respond more slowly compared to statements that are consistent with early beliefs, such as the idea that the moon goes around the earth (Shtulman & Valcarcel, 2012). This is because there is some interference from older, incorrect knowledge. It should also be noted that, while education improves performance (Donley & Ashcraft, 1992), it can also get in the way. Oberle, McBeath, Madigan, and Sugar (2005) reported what they called the *Galileo bias*, in which people mistakenly believed that if two balls of different weights dropped from 10 meters they will hit the ground simultaneously. However, this does not take into account air resistance. Even with extensive practice dropping these balls, students at Arizona State University continued to make errors based on semantic knowledge of what they had learned in elementary school about Galileo and gravity.

This incorrect understanding can be extended to semantic models of devices. For example, many people treat a thermostat not as a device for setting the ideal temperature (when the furnace should stop heating the house) but as a heat accelerator, setting the temperature much higher than the desired temperature in the mistaken belief that the house will get warmer faster (it will not).

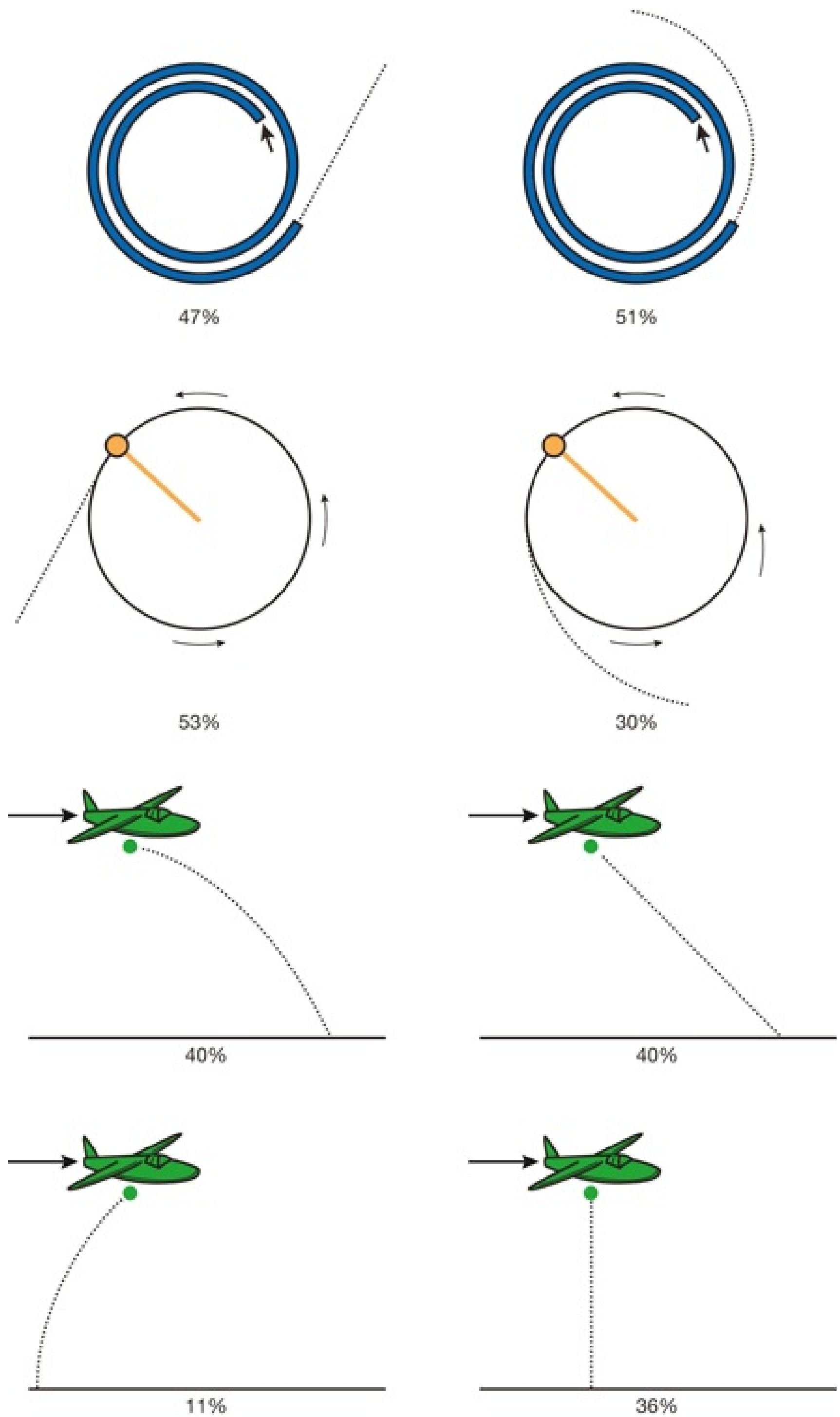

FIGURE 9.11 *Responses Given in Naïve Physics Studies*

Source: McCloskey, M. (1983). Naïve theories of motion. In D. Gentner & A. L. Stevens (Eds.), *Mental models* (pp. 299–324). Hillsdale, NJ: Erlbaum

Another source of misinformation in semantic memory is people's understanding of how vision works. Vision works by light energy entering the eye and being absorbed by the photoreceptors (rods and cones) in the retina. However, a large number (33 to 86%, depending on the measure) of college-educated people mistakenly believe that vision involves emissions from the eye (Winer, Cottrell, Gregg, Fournier, & Bica, 2002). This is the extramission view of vision and is reflected in people's responses when talking about or creating depictions of how vision works. This can include imagining rays coming out of the eyes or the belief that you can "feel it" when a person behind you is looking at you. This semantic misunderstanding of an intimate part of our experience illustrates the degree to which our knowledge may be completely erroneous.

Stop and Review

Our semantic memory is only as accurate as the information in it and how we use it. Breakdowns occur when knowledge is only superficially accessed, as in the Moses Illusion, or when semantic memories, although based on experience, have somehow been stored incorrectly, such as the errors people make on naïve physics tasks.

PUTTING IT ALL TOGETHER

This chapter looked at how you store and retrieve general world knowledge in semantic memory. Semantic memory is highly structured and this structure reveals itself in a number of ways. It is reflected in the ease with information is retrieved, as in priming and the organization of knowledge into categories, schemas, scripts, and order relations. All of these reflect a basic principle that memory is not the passive accumulation of knowledge and experiences. Memory is actively interpreting, abstracting, organizing, and structuring of what you have perceived and thought. The mind abhors randomness and seeks structure. Semantic memory is the derivation and imposition of structure onto our storehouse of experience. Sometimes the semantic structure of our memory is accurate and tells you how the world is, and sometimes it gets the world wrong and you misunderstand.

The organization of semantic memory reflects regularities in your world, both real and self-imposed. These regularities occur when semantic memory abstracts across many experiences to derive a general understanding of what is out there. Sometimes your semantic memory reflects this abstraction in the processing of knowledge apart from sensory-motor experiences. This is exemplified in a number of ways, such as the priming of concepts, the derivation of rules, prototypes, and averages with categorization, and the construction of schematic knowledge apart from individual events and their details. That said, semantic memory breathes, blinks, tastes, pushes, pulls, grabs, and moves. It's alive. It reflects how you perceive the world and interact with it. It is embodied. Your embodied semantic memory is reflected in how things are primed, how you see natural kinds, how you use tools and artifacts, and even how you use abstract ideas, like the number line.

STUDY QUESTIONS

1. What is semantic priming? What sorts of information gets primed? How far does it extend?
2. How long does it take for information to be established in semantic memory?
3. To what degree can semantic priming be consciously controlled? When are semantic memories inhibited?
4. How does the interconnectivity of information influence the ease with which it is remembered?
5. What are the basic properties of categories formed in semantic memory?
6. What are some of the major theories of how people form categories?
7. What is the classical view of human categorization and what are some of its major flaws?
8. What are the major types of probabilistic theories of categorization? What are their advantages and disadvantages?
9. What are explanation-based theories of categorization? How are they influenced by the concept of psychological essentialism?
10. How is semantic memory retrieval affected by the order of information along a dimension?
11. What is the SNARC effect and what does it reveal about how some information is stored in semantic memory?
12. What are the primary ways that schemas influence memory at encoding? At retrieval?
13. What are schemas for sequential event knowledge called? How do they operate?
14. How can a person avoid the influence of schemas and remember more accurately?
15. What sorts of problems can occur when semantic memory is used? How do

these errors arise?

16. How is semantic memory influence by embodied/perceptual aspects of experience?

KEY TERMS

- abstraction
- ad hoc categories
- artifact categories
- categorization
- category
- central tendency
- classical view of categorization
- concept
- exemplar theory
- explanation-based views
- family resemblance
- graded membership
- inhibition
- integration
- interpretation
- levels of categorization
- mediated priming
- Moses Illusion
- naïve physics
- natural kind categories
- prime
- priming
- prototype model
- psychological essentialism
- reconstruction
- schema
- scripts
- selection
- semantic memory
- semantic congruity effect

- semantic distance effect
- semantic memory
- serial position effect
- SNARC effect
- target

EXPLORE MORE

Here are some additional readings that can allow you to more deeply explore some of the basic principles of semantic memory.

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NOTES

1 See also Gevers, Reynvoet, and Fias (2004) for a day of the week effect, and Prado, van der Henst, and Noveck (2008) for a linear order effect.

2 If you have more than one schema, they are called either schemas or schemata—both plurals are acceptable.

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PART 3

Special Topics in Memory

CHAPTER 10

Formal Models of Memory

Verbal descriptions of memory are nice. They give us a feel for how it operates but they can be vague. Worse, alone they may not distinguish among the different theories of memory. A more precise language is needed to capture the subtle flavors and nuances of memory, and that language is mathematics. By casting ideas in a mathematical language, thereby creating a **formal model**, we can look at finer qualities of memory that are not possible with verbal descriptions. This mathematical expression is often done using computer models. Creating a formal model of memory forces us to be explicit about how things work. Thus, our assumptions are laid bare. For verbal descriptions it's easy to fudge things and make assumptions without realizing it. Moreover, formal models allow for more accurate predictions. If psychology is to continue to succeed as a science, there should be a reasonable level of predictability, given a certain amount of starting knowledge. This does not mean that the goal is to predict every little behavior or thought but it must at least provide a general description of what will happen on average. An example of a reasonable prediction is knowing that people remember more if they spread studying out over several short sessions rather than a single long one.

Formal models provide a degree of precision and accuracy that is not possible with verbal descriptions. Formal models play the important role of explicitly pointing out theoretical errors and allowing a range of researchers to test various aspects of a theory (Farrell & Lewandowsky, 2010). Hintzman stated the following:

> The common strategy of trying to reason backward from behavior to underlying process (analysis) has drawbacks that become painfully apparent to those who work with simulation models (synthesis). To have one's hunches about how a simple combination of processes will behave repeatedly dashed by one's own computer program is a humbling experience that no experimental psychologist should miss.

(Hintzman, 1990, p. 111)

This chapter covers a number of formal models of memory. First, we look at two simple models of recognition and recall and how a formal comparison of these simple models has led to interesting and unexpected insights. Next, we cover four classes of theories: (1) network models of memory, which emphasize associative structure; (2) global matching models, which assume that memory is accessed as a whole and that structure emerges from this process; (3) parallel distributed models, which use the nervous system as their inspiration; and (4) dual process models, which assume there are two fundamentally different types of memory processes.

Before turning to the models themselves, you should be aware that these models rely heavily on quantitative descriptions. However, this chapter has relatively few formulas. The intent is to provide you with a general overview of how these models characterize memory while assuming neither a degree of mathematical sophistication nor the ability to apply that knowledge.

SIMPLE MODELS OF MEMORY

We first examine two relatively simple models of memory and then move on to more developed ideas. The first theory is the threshold model of recognition, followed by the generate–recognize model of recall.

Threshold Model

The first simple model of memory, the **threshold model** (Anderson, 2000; Murdock, 1974), is the idea that there is a threshold of activation that a memory trace must exceed for it to be identified as “old” (or recognized). Moreover, there may also be some threshold below which information is clearly identified as “new.” Memories that fall between these two thresholds are ambiguous and so people may make a guess as to what response to make. This is illustrated in Figure 10.1.

These thresholds are subjective levels that people use (consciously or unconsciously) to evaluate whether items are old. Now, not all memories that people consider old have actually been encountered before. Some are new but, for some reason, people recognize them as old. These incorrect responses are essentially guesses. Thus, we must account for how much guessing is going on to better understand memory. For example, if people answer “yes” to all of the old items on a test but never say “yes” to a new item then we can conclude that memory is very good. However, if people answer “yes” to all of the old items but also always answer “yes” to all of the new items, this is a much less impressive feat. So, we need to correct for guessing.

To **correct for guessing** the threshold model uses the probability of correctly recognizing, as well as the probability of incorrectly identifying something as old (a guess). Here *p* is the probability of correct recognition and *g* is the probability of guessing correctly. The “|” sign stands for “given that.” So, the probability of giving a correct “yes” response can be written as:

$$P(\text{“yes”} \mid \text{old item}) = p + (1 - p)g$$

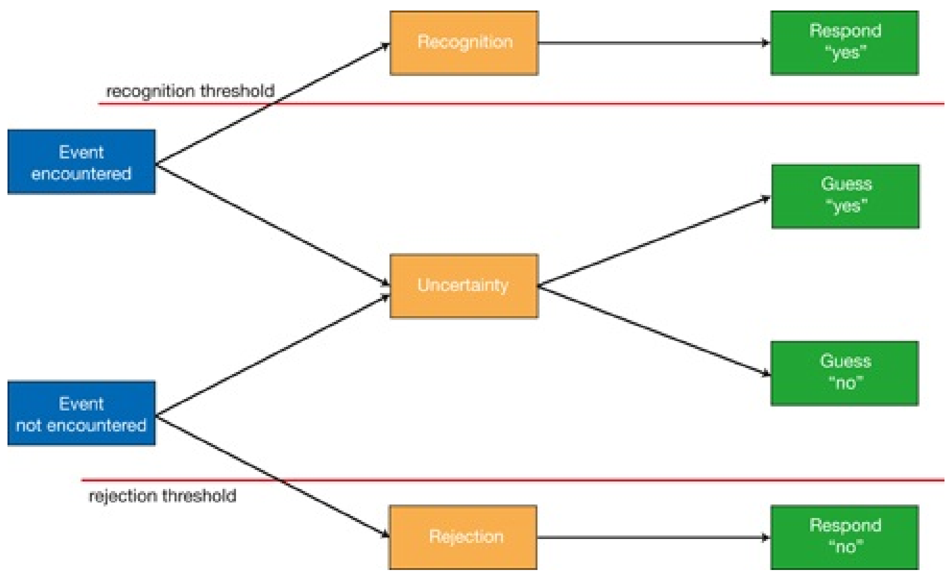

FIGURE 10.1 *Illustration of the Threshold Model of Recognition*

Using this formula and logic, the terms can be rearranged to gain an estimate of the likelihood that people are actually recognizing rather than guessing.

p = P(“yes” | old item) − P(“yes” | new item)
1 − P(“yes” | new item)

This model of memory is related to ideas in **signal detection theory** (see Chapter 3), which is a more sophisticated development. As a reminder, when a memory of an old item exceeds the threshold, people correctly recognize it. This is a **hit**. When an old item’s activation level fails to reach the threshold, it is rejected. This is a **miss**. When a new item is rejected because the memory does not exceed threshold (because it is new), this is a **correct rejection**. Finally, if a new item has a representation in memory that exceeds threshold, people inappropriately identify it as old. This is a **false alarm**. Signal detection approaches also play a role in the global matching models discussed later in the chapter.

Generate–Recognize Model

The other simple model is the **generate–recognize model** of recall (Anderson & Bower, 1972; Bahrick, 1970; Kintsch, 1970). This model assumes that recall, particularly free recall, is a two-stage process. Recall is not just recognition with a higher threshold. Instead, recall involves a search of memory, whereas recognition simply involves people indicating whether items are familiar. Still, it would be nice if the retrieval involved in recall were not completely different from recognition. The generate–recognize model tries to accomplish both of these aims.

The first stage of the model is a generate component, which is unique to recall. During this phase, people take the available retrieval cues to generate a set of memory traces whose contents can be reported. This is done by activating information in memory that is associated with the cues, followed by the information that is associated with that, and so on. This information is cross-referenced to generate a set of possible responses. In the second stage, people apply the standard recognition processes to the information that was generated in the first stage.

This model, although relatively simple, makes clear predictions about how retrieval operates. One is that recall is more difficult than recognition because there are more steps involved. Another is that recall should be more influenced by associations between concepts in memory. Finally, this model also predicts that everything that affects recognition should also affect recall because recognition is a subprocess of recall.

Recognition Failure

As described in Chapter 3, recall and recognition are common ways to assess memory. The generate–recognize model is an explanation of how recall and recognition may be related to one another. This section provides a quantitative comparison of this relationship. In some ways, recall and recognition seem similar—for example, they are both direct memory measures—but there are important differences, such as the degree to which they are influenced by the organization of information during learning. Suppose people learn lists of words that are either grouped by categories (organized) or are presented randomly (unorganized). In general, the organized list is better recalled than the unorganized list. However, recognition is less affected by this, if at all (Kintsch, 1968). This is consistent with the generate–recognize model.

However, there is a problem. In many experiments of reasonable scope, there are a number of items that may be recalled but not recognized. This is called **recognition failure** and it is a problem for the generate–recognize theory. If all of the processes that operate during recognition also operate during recall, then anything that is recalled should be recognized. However, recognition failure is a regular occurrence. This consistency is shown in Figure 10.2. In this graph, if everything that could be recognized was also recalled then the data points should all fall along the diagonal (with some random error), but this does not occur. Instead, there is a systematic deviation, with points falling above the diagonal, indicating recognition failure (not recognizing items that were recalled). A formal description of this phenomenon, the **Tulving–Wiseman function** (Tulving & Wiseman, 1975), conveys this relationship mathematically. For this function, Rn stands for recognition and Rc stands for recall. (And, as a refresher, *p* stands for "probability that" and "|" stands for "given that.")

$$p(\mathrm{Rn} \mid \mathrm{Rc}) = p(\mathrm{Rn}) + .5[p(\mathrm{Rn}) - p(\mathrm{Rn})^2]$$

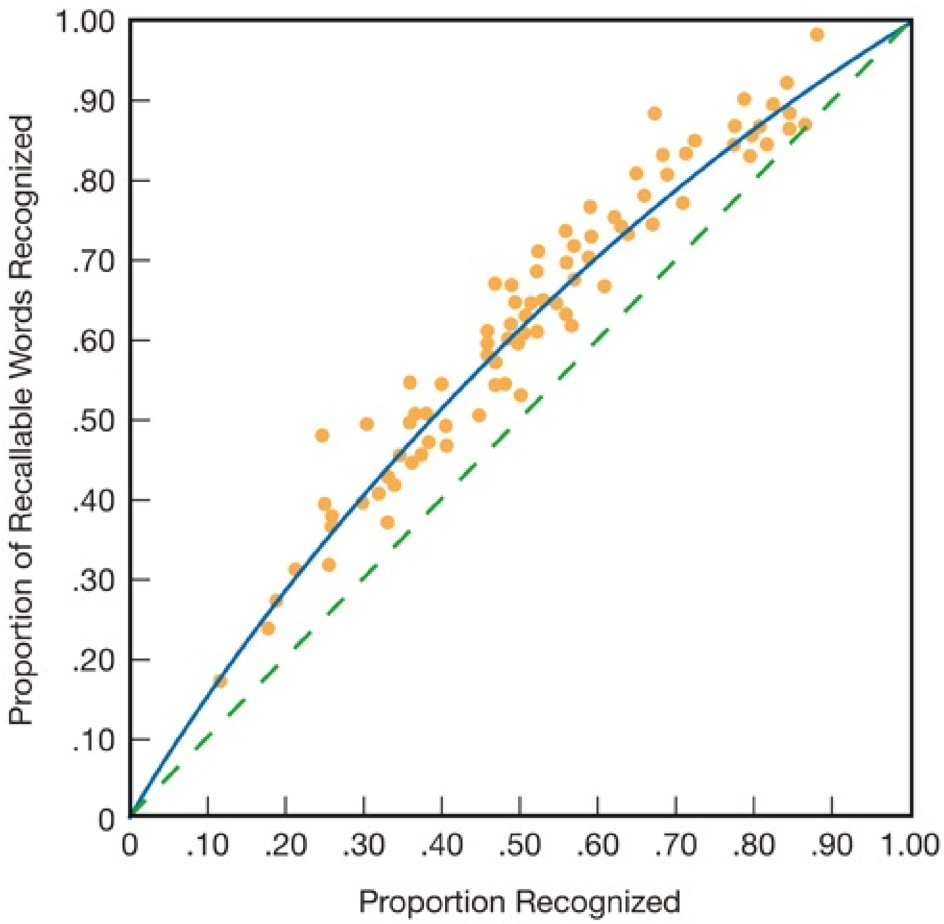

FIGURE 10.2 *Data Plot Illustrating Recognition Failure and the Tulving–Wiseman Function*

Source: Flexser, A. J., & Tulving, E. (1975). Retrieval independence in recognition and recall. *Psychological Review*, *85*, 153–171

The explanation for this function is that recall and recognition use different types of retrieval cues (Flexser & Tulving, 1975; but see Hintzman, 1992). Recall uses cues to prompt retrieval, whereas recognition uses the item itself. For example, whenever I need to make copies on my departmental copier the machine asks for the last four digits of my phone number. There are times that I find this difficult to remember without recalling the first three digits (the exchange) first. This is a case where I have my phone number stored in such a way that the retrieval of the last four digits is highly associated with the context of the first three. If I saw only the last four digits without such a context, it would not surprise me if I did not recognize it as part of my phone number. This differentially based retrieval, which uses different memory cues, with relative independence between recall and recognition, is at odds with the generate–recognize model and was brought to light only with a formal analysis of the data.

To address this issue with the basic generate–recognize model, there has been an appeal to the idea that recall and recognition have some overlapping retrieval processes. Jacoby and Hollingshead's (1990) modification was a generate–*sometimes* recognize model. For this view, the recognition step is sometimes skipped if the generate process occurs rapidly and fluently. The idea is that, when information is generated so easily, no recognition step is needed. Thus, recognition failure could occur because this step is sometimes skipped, causing something to be recalled without being recognized.

STUDY IN DEPTH

Guynn et al. (2014) did a study that supports the generate–recognize model if one assumes that information that is generated is only *sometimes* recognized, as suggested by Jacoby and Hollingshead (1990). This was done using 72 students from the University of New Mexico. They investigated this issue by varying how people encoded information into memory. We focus only on part of this rather complex study.

At learning people encoded items by emphasizing either item-specific or relational information (see Chapter 7). To induce *item-specific* processing, people either read a series of words (e.g., "turtle") or did an anagram task of unscrambling the first two letters to derive the words (e.g., "turtle"). The anagram task places a greater emphasis on item-specific processing because people focus more mental effort on the individual words and less on how the words may be related to each other. In comparison, to induce *relational* processing, people either simply wrote words down or sorted them into several, experimenter-provided categories (e.g., four-footed animals). Category sorting places a greater emphasis on relational processing because items are related to the larger categories. After learning, all participants did a three-minute distractor task in which they solved a series of math problems.

To assess the modified generate–recognize model, they gave one of two types of memory tasks. One of these was a category production task. People were given category names (e.g., four-footed animals) and were told to generate as many members of that category as possible. This reflect the process of generation, but not recognition because, while people need to generate information from memory, there is no need for recognition: there is no explicit need to compare what is generated with what was encountered before. Any influence of the prior learning is largely implicit. The second memory task was a category cued recall task. People were given category names and were asked to use them to help remember any of the items that were encountered previously. Thus, this involves both generating information from memory, as well as a recognition process to assess whether the generated items were encountered before.

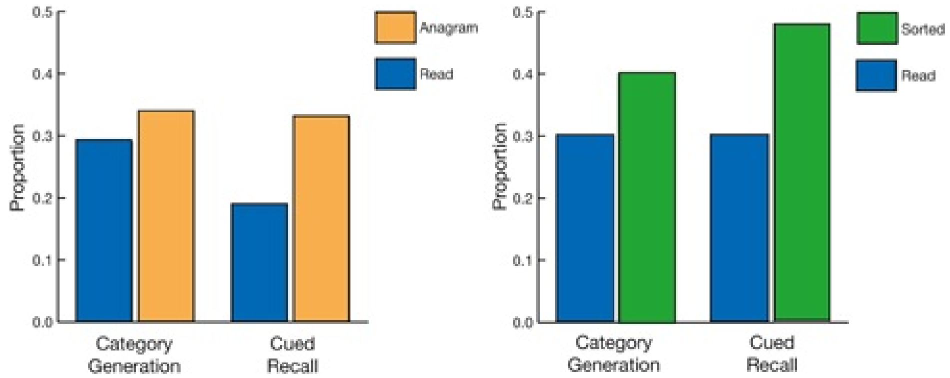

FIGURE 10.3 *Partial Plot of Data of Guynn et al.'s (2014) Study Exploring the Viability of the Modified Generate–Recognize Model of Recall*

Adapted from: Guynn, M. J., McDaniel, M. A., Strosser, G. L., Ramirez, J. M., Castleberry, E. H., & Arnett, K. H. (2014). Relational and item-specific influences on generate–recognize processes in recall. *Memory & Cognition*, *42*(2), 198–211

The pattern of performance, shown in Figure 10.3, is that item-specific processing during learning (anagram solution) had only a minor effect on the category generation, but did affect cued recall. Thus, item-specific encoding influenced recognition but not generation. In comparison, relational learning (category sorting), influenced the generation component because performance was different in both the generation and cued recall tasks. Moreover, while there was a difference between categorized and uncategorized items, there was no significant difference when the anagram task was done, suggesting that the generation component was largely unaffected by category sorting. Thus, the result was that generation and recognition processes could be separately affected, and that both are involved during recall.

Stop and Review

Simple models capture basic aspects of memory. For the threshold model, memories are retrieved when activation exceeds a threshold, in a similar way to signal detection models. The generate–recognize model of recall incorporates all of the essential characteristics of recognition into the retrieval process. As appealing as the generate–recognize model is for its simplicity, the recognition failure effect suggests caution. That said, a generate–sometimes recognize model may overcome this.

NETWORK THEORIES

In Chapter 1 we saw that the work of Aristotle had a profound influence on memory theories through his ideas about associations. The influence of associations on memory is seen with priming, encoding specificity, and the structure of semantic memory. Many formal models have taken this idea of associative structure and used it as the fundamental basis for their theories of memory. One of the clearest ways to see this is with network models. These are mental representations in which there are large numbers of smaller units, often called **nodes**, joined together in a tangled web of associations by an even larger number of **links**.

Semantic Networks

The first major **network theory** of memory was by Collins and Quillian (1969, 1972) to capture semantic memory in the service of a computer program that would hopefully be able to use human language in a natural way (a goal that, while getting closer, is still far off). In **Collins and Quillian's network model** of semantic memory, the nodes were simple concepts, like *bird* or *canary*, and the links were of several types. Figure 10.4 shows a portion of a network, with property associations and categorical associations. For property associations, some concepts are properties of other concepts that they are associated with. For example, *feathers* is a property of *bird*, *yellow* is a property of *canary*, and so on. Other associations were super-ordinate category relations—for example, "a canary is a bird." In semantic networks, information is generally stored in one location in the network using a cognitive economy. That is, rather than expending effort endlessly replicating concepts, individual concepts can be instantiated in the network only a few times or even just once.

When people access a concept in memory, like *canary*, a search process begins by having activation move along all the links associated with that concept. This process is **spreading activation**. A way to think about spreading activation is as electricity flowing through the wires of a circuit. Through spreading activation, if the concept *feathers* were also accessed the links associated with it would be searched. When two search paths meet to create an intersection, people can verify that the concepts are associated and stored in memory. If the two searches do not form an intersection, because they are not connected in memory, then the information is not something that is known. For example, if you were asked whether a canary has feathers the nodes for *canary* and *feathers* would be activated and the activation would spread along the links associated with these nodes. These spreads of activation would eventually meet and you could verify that the fact is known. However, if you were asked whether a canary has gills, the nodes for *canary* and *gills* would be activated and the activation would spread along the links associated with these nodes. However, these spreads of activation would not meet and you could verify that this is something not known.

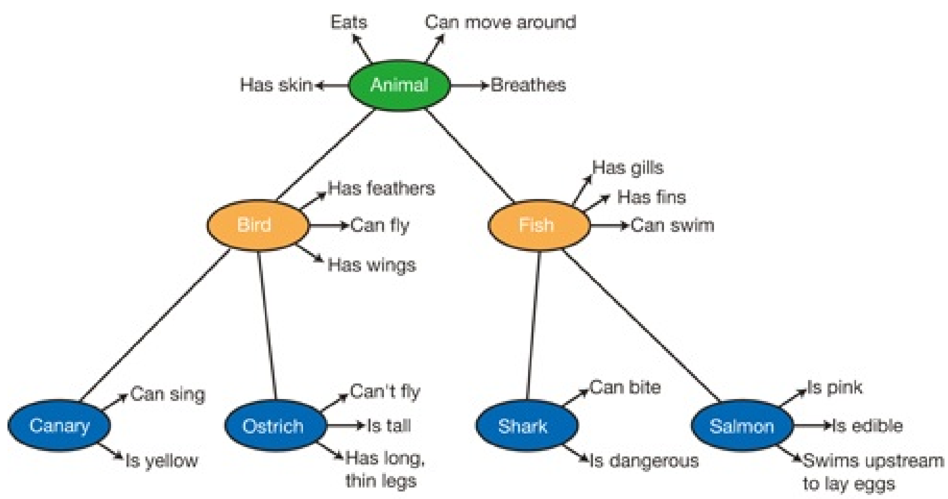

FIGURE 10.4 *Portion of a Network in Collins and Quillian's (1969, 1972) Model of Memory*

Adapted from: Collins, A. M., & Quillian, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior*, *8*, 240–247

A prediction of this model is that the speed with which information is retrieved is a function of the distance between two nodes in the network. For example, people should be faster to verify that "a canary is yellow" than "a canary has feathers." Although initial studies supported this idea (Collins & Quillian, 1969), subsequent work revealed some problems. For example, if nodes in a hierarchical structure are far from one another, it should take longer to verify one of those facts. However, some facts are verified quicker than should be possible according to these models (Rips, Shoben, & Smith, 1973). For example, people verify that “a pig is an animal” faster than “a pig is a mammal,” even though the opposite is predicted.

While Collins and Quillian’s networks were defined in terms of hierarchical relations, this idea was replaced with the idea of memory being structured in terms of degree of relatedness (Collins & Loftus, 1975; Ashcraft, 1976). Figure 10.5 illustrates this kind of memory network. For example, *green* can be thought of being more closely associated with colors because there are more links to other colors. However, *green* is less associated with *raking* because, in this network, there are not many links between the *green* to the *raking* nodes. Also, the relative strength of individual associations is captured by the length of the links connecting the concepts, with shorter links standing for stronger associations. For example, while *emerald* is associated with both *green* and *diamond*, it is more closely associated with *diamond* than *green* because the association is stronger. The approach of trying to understanding how people’s semantic networks are structured continues to influence lines of research (Morais, Olsson, & Schooler, 2013).

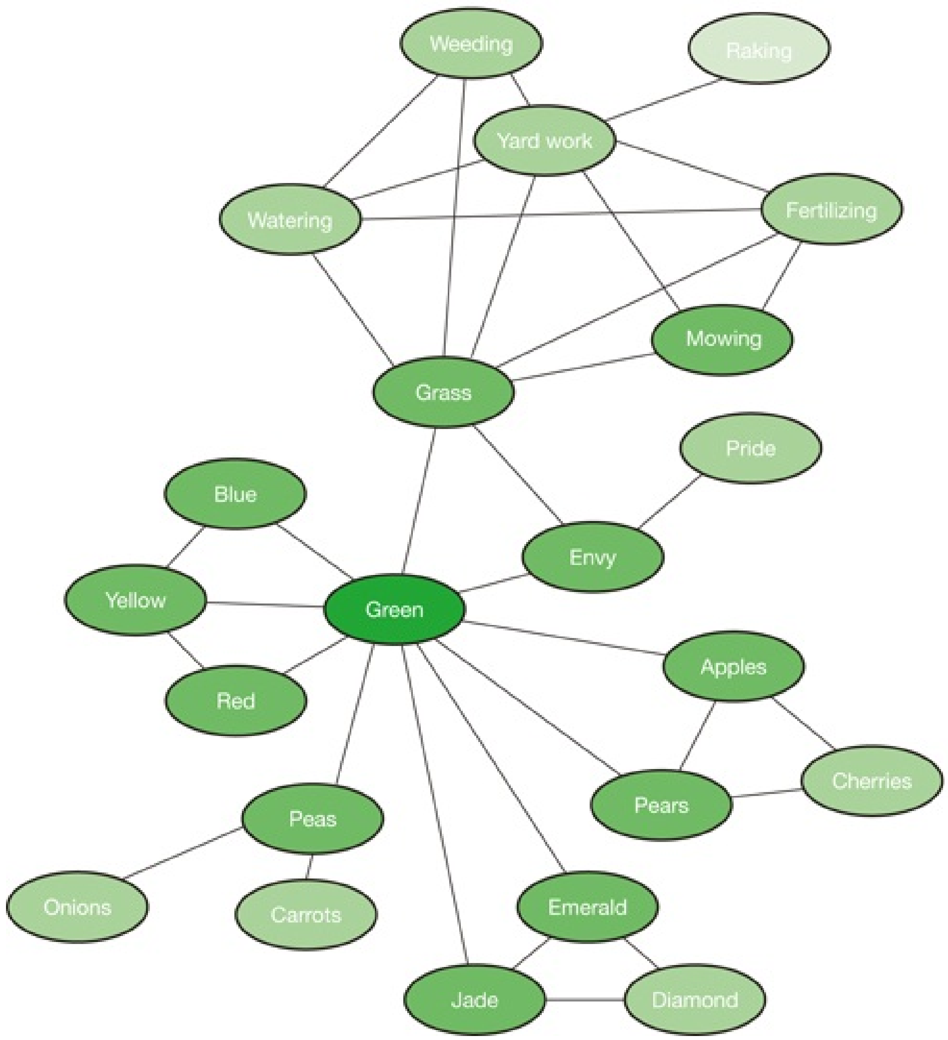

FIGURE 10.5 *Portion of a Network in Collins and Loftus's (1975) Model of Memory*

Adapted from: Collins, A. M., & Loftus, E. F. (1975). A spreading activation theory of semantic processing. *Psychological Review*, 82, 407–428

PHOTO 10.1 *For many people, it is easy to think of memory as being a network of interrelated and interconnected ideas*

Source: whilerests/iStock/Thinkstock

Network models provide straightforward accounts of **priming**. As a reminder, when people encounter information, this not only activates those particular concepts but makes related concepts more available as well. For a network model, priming occurs because a concept is activated and then this activation spreads along the links to related concepts. This is why it is easier to shift your thinking to related ideas (because they are already primed) than to something completely different.

An attractive idea behind network theories of memory is that everything is defined in terms of everything else, much like a dictionary. However, this is also a major problem (Johnson-Laird, Hermann, & Chaffin, 1984) as there is no clear way to ground knowledge in the world, an issue that theories of embodied or grounded cognition seek to address.

ACT

Another network model of memory is the **ACT** (Adaptive Control of Thought) model (Anderson, 1976, 1983, 1990). Of all the models discussed here, this is the most comprehensive in that it is a general model of cognition, not just memory. For ACT, knowledge is stored in a **propositional network**. A proposition is a simple idea unit. In the memory network, a proposition is defined as two nodes and a link. Information is retrieved through a process of spreading activation, similar to other network models. An example of a propositional network for the sentence "the sleepy student is in the old classroom" is given in Figure 10.6. This sentence is made up of a number of propositions that are organized by the network.

One important property of ACT is the distinction between type nodes and token nodes. **Type nodes** are general concepts, like those seen in the semantic networks. For example, a *bird* type node stands for birds in general. In addition, **token nodes** correspond to specific instances. For example, a *bird* token node would stand for a specific bird, such as "that robin over there."

The ACT model also has the idea that there is a limited amount of activation available in the system. Not all associations with a concept in memory are searched equally well, simultaneously, and to a high degree. Instead, activation is a limited resource. The more associations with a concept, the more finely divided the activation becomes and retrieval time is slowed down accordingly. This is ACT's explanation for the fan effect (see Chapter 8). In essence, the more facts people learn about a concept, the more associations that are linked to it. When they need to verify any one of those facts, the number of associations with that concept divide up the activation and retrieval along any one of those pathways is slowed (Anderson, 1974).

Another characteristic of ACT is the distinction between production and declarative memory. The network of propositions is the declarative memory part of the model. The other part is **production memories**, which are the mental steps people proceed through to go from one state of knowing to another. These productions manipulate information and are executed when the appropriate conditions in working memory match the relevance of the production. They are basically, "if . . . then" statements in long-term memory. If a condition is present, then the information is manipulated in a specified way. For example, when you learned addition in your elementary school math class, you developed production memories for how to manipulate the number information as it was encountered in problems you were given.

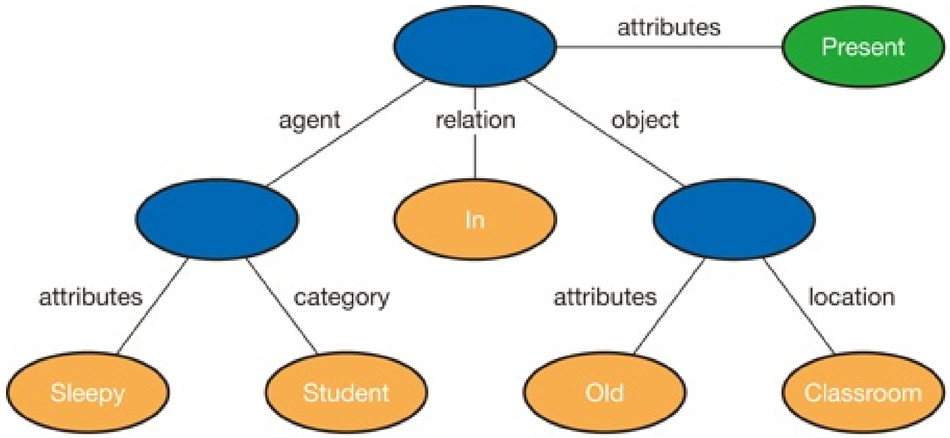

FIGURE 10.6 *ACT Model Propositional Network for the Sentence "the Sleepy Student is in the Old Classroom"*

TRY IT OUT

The aim of this Try It Out is for you to observe the fan effect as predicted by the ACT model. For this task you first need a set of sentences for participants to memorize. The important things when creating your list is to make the sentences relatively simple and for there to be two identifiable concepts in each sentence with which other sentences can potentially share associations. For example, you may have your participants memorize sentences about people in locations of the form "the *person* is in the *location*." such as "the banker is in the museum." For each sentence, there should be one to three associations with each concept. For example, there could be one to three locations that each person is in and one to three people in each location. In Anderson's (1974) original experiment, he had 28 such study sentences. After you create your study sentences, you also want to create a set of foil sentences for the recognition test. These incorrect sentences should be recombinations of concepts from studied sentences. For example, if people memorized "the banker is in the museum" and "the architect is in the hotel," then the unstudied sentences could be "the banker is in the hotel" and "the architect is in the museum."

For this study you need at least 16 participants. At the beginning, have your participants memorize the sentences. Do this by presenting the sentences one at a time in a random order. Fix the amount of time people can see each sentence, such as seven seconds. After people go through the entire list, have them try to answer questions about the two types of concepts, such as "where is the *person*?" and "who is in the *location*?" If there is more than one answer for a question, then the person should have to recall all of them. If they get an answer wrong, tell them the correct answer. After going through all of the test questions, have people go back and study again. Repeat this study–test procedure until a participant can answer all of the test questions. At that point, they will have memorized the facts and will now be ready for the recognition test.

For the recognition test, use the entire sets of studied and foil sentences. These should be presented one at a time. The task is to indicate whether each sentence was studied or not. Because people memorized the sentences, accuracy is going to be very high. You need to collect response times. Try to use a computer to do this. To get better data, repeat the number of times each studied and foil sentence is presented. Perhaps eight times each.

Average the response times for each fan level (number of associations) for the two concepts in the study sentences. What you should observe is that as the number of associations increases there is an increase in response time. This illustrates the prediction of the ACT model that a greater number of associative links "fanning" off of a concept node divides the amount of spreading activation. The more finely this activation is divided, the longer it takes to build up and retrieve any one idea and the slower the response time.

These productions are initially slow and cumbersome to execute. However, they become more automatic and unconscious with more practice. For example, when you solve a math problem—such as "574 × 63 = ?"—you invoke mental procedures to arrive at the correct answer. The more practice you have, the stronger the productions become and the easier it is to solve the problems. At some point, your ability to solve such math problems is nearly automatic.

Production memories interact with the declarative memory through working memory. For ACT, working memory is that part of the declarative network that is currently active along with the productions that are operating on it. The addition of a production memory makes ACT a powerful tool. It allows for explanations of memory based on not only how information is structured but how people manipulate it and the consequences this has for long-term memory.

Latent Semantic Analysis (LSA)

The idea of relating concepts to one another, the essence of most network models of memory, has been incorporated into other theories, even if they are not strictly network models. One of these is **latent semantic analysis**, or **LSA** (Landauer & Dumais, 1997). In LSA, a large number of texts (nearly a million) are fed into the program. From that input, a high-dimensional space (over 300 dimensions) is created to evaluate the co-occurrences of words in the language. Meaning is determined by assessing which words occur in similar contexts. Thus, if two words are perfect synonyms of each other, they would occur in the same contexts, although they would rarely ever occur together (because that would be redundant). Thus, the values derived from LSA can be indices of how similar two concepts are in memory (Kintsch, 2014).

Knowledge is represented in LSA as the relations among concepts in the high-dimensional semantic space. In this way, the model “acquires” a large set of knowledge in a way that can mimic human performance, without a programmer directly hardcoding the relations among concepts. This is the latent part of latent semantic analysis. These relations just fall out of the high-dimensional structure. This model has been successfully applied to a number of tasks including grading essay exams (Steinhart, 2001), metaphor comprehension (Kintsch & Bowles, 2002), and problem solving (Quesada, Kintsch, & Gomez, 2001).

Stop and Review

Network theories of memory have been influential. Semantic network models provided clear, testable predictions that were, at least initially, verified in studies with people. However, subsequent work quickly discredited the hierarchical structure idea. Network models have continued to develop. The concept of spreading activation pervades a lot of thinking about memory retrieval, especially in accounts of priming. The ACT model has a propositional network for storing information in long-term memory, along with a production memory for altering the contents of memory. Finally, LSA uses co-occurrences in a sophisticated way to automatically derive contextualized meanings.

GLOBAL MATCHING MODELS

For network models, knowledge is stored in a complex, highly organized, and highly integrated structure, in which portions of the network become selectively activated to meet the demands of the current task. In comparison, for **global matching models**, memories are accessed through processes that consider the entire set of traces available. Any relation between different memories occurs at retrieval. That is, structure in memory emerges out of the process of retrieval rather than being a part of long-term storage, as with network models.

In these models information is either stored as separate memory records, in what are called **multiple-trace models**, or it is patterns of information imposed on a common framework, in what are called **distributed storage models**. In global matching theories, multiple memory traces are activated in parallel. What is retrieved is a function of (1) the familiarity of the memory probe, (2) the degree of overlap between the probe and the memory traces, and (3) the amount of activation of the memory traces related to the probe (Clark & Gronlund, 1996).

In general, global matching models have evolved out of signal detection theories of retrieval (see Chapter 3). The availability of memory traces is a function of their familiarity (discrimination) and successful retrieval involves activation reaching a given threshold (bias). Two multiple-trace models, SAM and MINERVA 2, are considered here. We also examine two distributed storage models, TODAM and CHARM.

Search of Associative Memory (SAM)

One multiple-trace model is the **search of associative memory**, or **SAM** (Gillund & Shiffrin, 1984; Raaijmakers & Shiffrin, 1980, 1981, 1992). For SAM, memories are stored in traces that contain content, associative, and contextual information. Remembering occurs when a cue (something in the world or a thought) overlaps with features in a trace, causing it to become active and potentially be retrieved. Memory retrieval is probabilistic—that is, the probability that a given trace is remembered is a function of its relation to the memory probe and its strength relative to other traces. The greater the strength, the higher the probability of retrieval.

The **recall** process for SAM is shown in Figure 10.7. Initially, people are given a recall cue, such as a question. To organize the information that needs to be recalled, even if it is a modestly complex set, people create a retrieval plan to keep track of the information. This retrieval plan generates a series of probe cues to access memory traces using a global matching process. During the memory search, the model first restricts itself to a subset of traces that are more likely to be relevant. It then searches through them, starting with the stronger ones and moving to the weaker ones. This search process, which focuses on memory traces more resonant with the retrieval cues, closely resembles spatial foraging behavior in animals (Hills, Jones, & Todd, 2012). In other words, a patch of memory is searched until the likelihood of retrieving a new memory trace is low, then the search moves on to another patch.

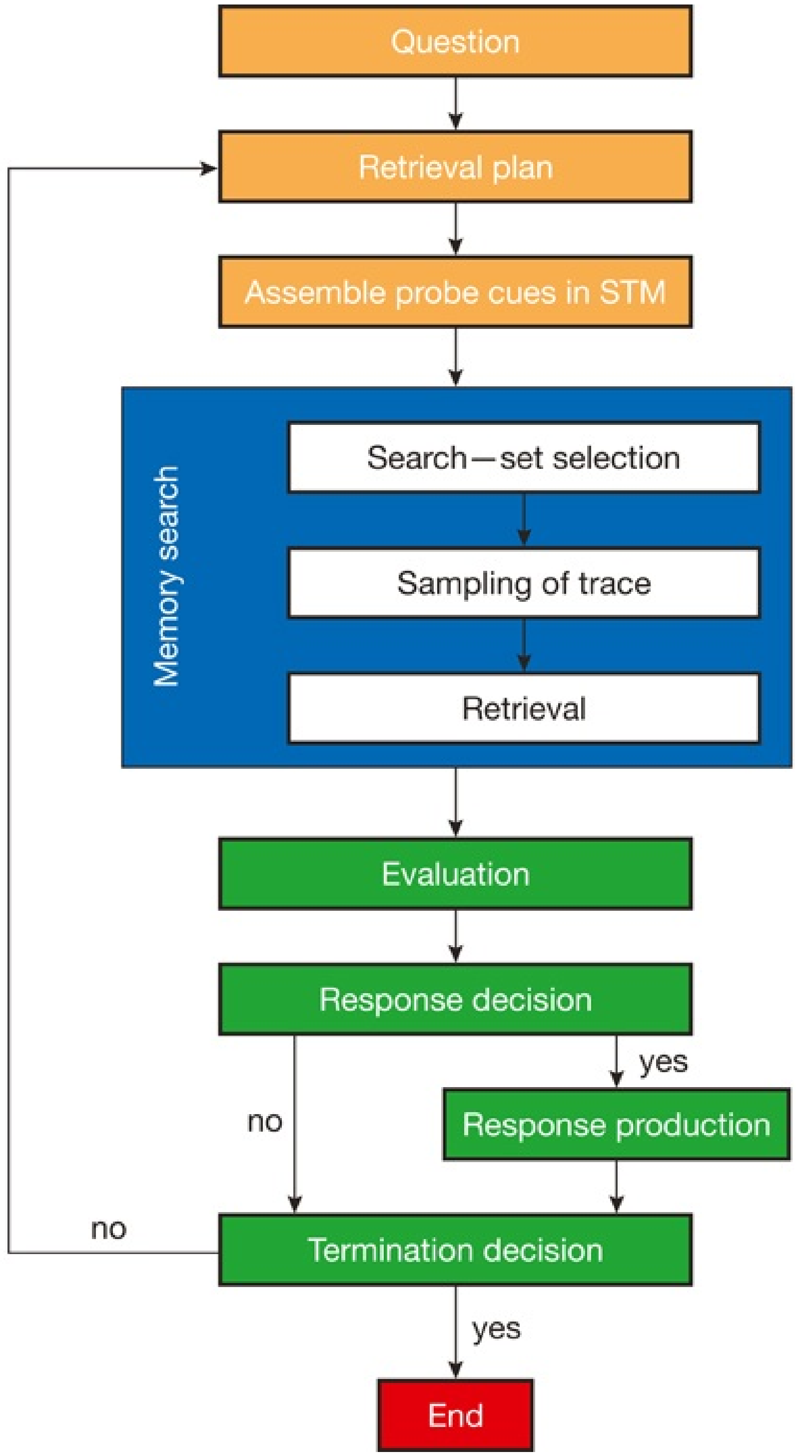

FIGURE 10.7 *The Processes Involved in Recall in the SAM Model of Memory*

Source: Raaijmakers, J. G. W., & Shiffrin, R. M. (1981). Search of associative memory. *Psychological*

Review, *88*, 93–134

These memory traces are recovered into short-term memory, where they are evaluated and either reported (output) or not (similar to the generate–recognize model). Then people either continue to search memory for more information or quit. The decision of when to stop searching are guided by the probability of more retrieval attempts being successful (Dougherty, Harbison, & Davelaar, 2014). So, information is retrieved through a sampling process that is influenced, but not completely determined, by how much memory traces are related to a retrieval cue. Traces that more closely match a cue are more likely to be retrieved and evaluated. If they are relevant, they are reported, otherwise they are not.

In comparison, for **recognition**, whether an item is recognized is a function of the sum of all of the memory traces related to a probe, as shown in Figure 10.8. First, information in both the recognition probe and its context are used to sample memory. This makes contact with all of those traces that share those features with the probe and the context. Context information helps narrow down the set of traces, thereby making retrieval more accurate. If the familiarity value that is returned from this sampling process is above threshold, then people accept the information as old (it is recognized). Otherwise, it is classified as new (it is not recognized). Thus, something may be recognized because people have a large number of weak memories, not just a single strong memory.

So, recognition extracts memories one at a time, starting with those that resonate most strongly with the retrieval cue. This includes information both in the cue itself and in the surrounding context. If this process produces a response that is strong enough, then people recognize the information as old. Otherwise, it is rejected as new.

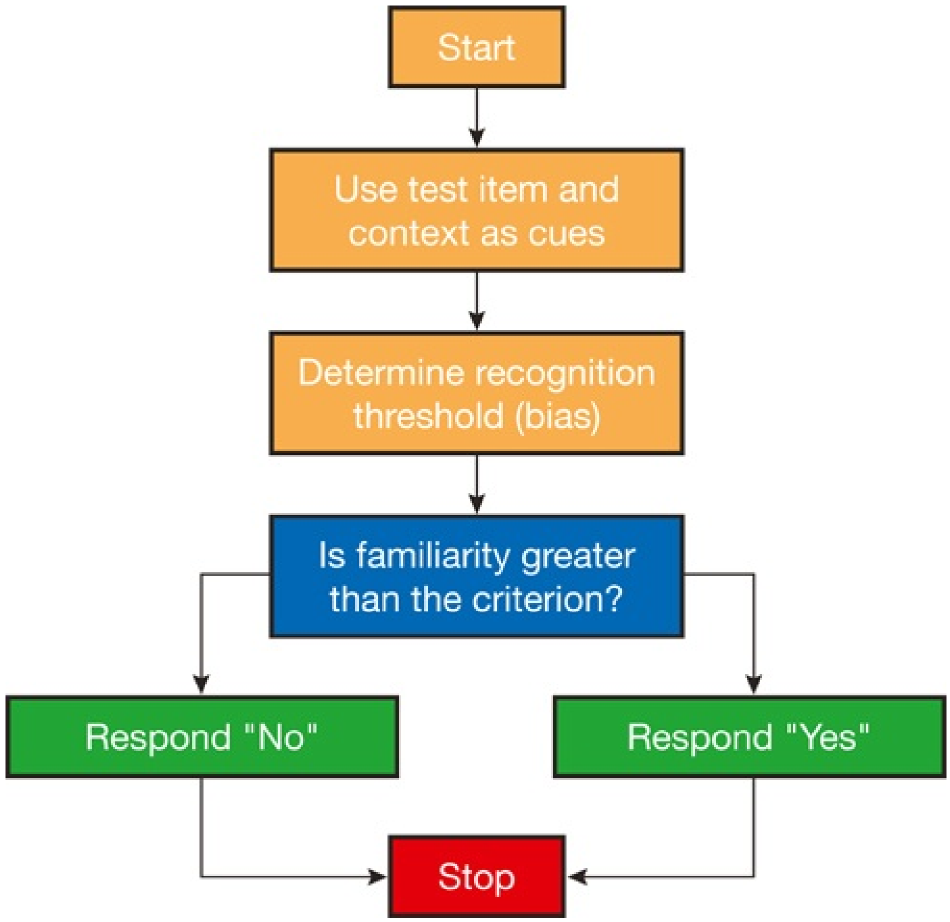

FIGURE 10.8 *Processes Involved in Recognition in the SAM Model of Memory*

Source: Gillund, G., & Shiffrin, R. M. (1984). A retrieval model for both recognition and recall. *Psychological Review*, *91*, 1–67

MINERVA 2

Another multiple-trace model is **MINERVA 2** (Hintzman, 1986) (MINERVA 1 didn't last very long). This theory assumes that memory traces are strings of features of the original event. Each feature, either content or context information, is represented by a value indicating its presence or absence. For MINERVA 2, what is retrieved is not a single memory trace (as in SAM). Instead, what is returned is a new memory trace called an **echo**, which is a weighted composite of all the traces that were activated. We examine two characteristics of the echo in detail: echo intensity and echo content.

Echo intensity is the activation strength of the echo that is returned by retrieval. This is a function of the intensity of the traces that were tapped by retrieval (see Figure 10.9). This is analogous to the familiarity value returned in

SAM. The greater the overlap between the cue and the echo, the greater the activation. So, if a memory probe activates memory traces with a high degree of overlap, then echo intensity is greater. For example, you have many memories of people speaking your name. Thus, if your name were a memory probe, the echo would have a high level of intensity because of the high degree of overlap. In contrast, you are likely to have very few to no memory traces about St. Ignatius High School football during the early 1980s. Although this information makes contact with some memories—such as those about football, high school, and the 1980s—there is likely little overlap with this memory probe as a whole and the echo intensity is weak, thereby indicating that this information is not known. Echo intensity is also useful in determining event frequency (e.g., how often have you been to the grocery store in the past two weeks?). More high-intensity echoes reflect frequent occurrences, whereas low-intensity echoes reflect rare events (Hintzman, 1988).

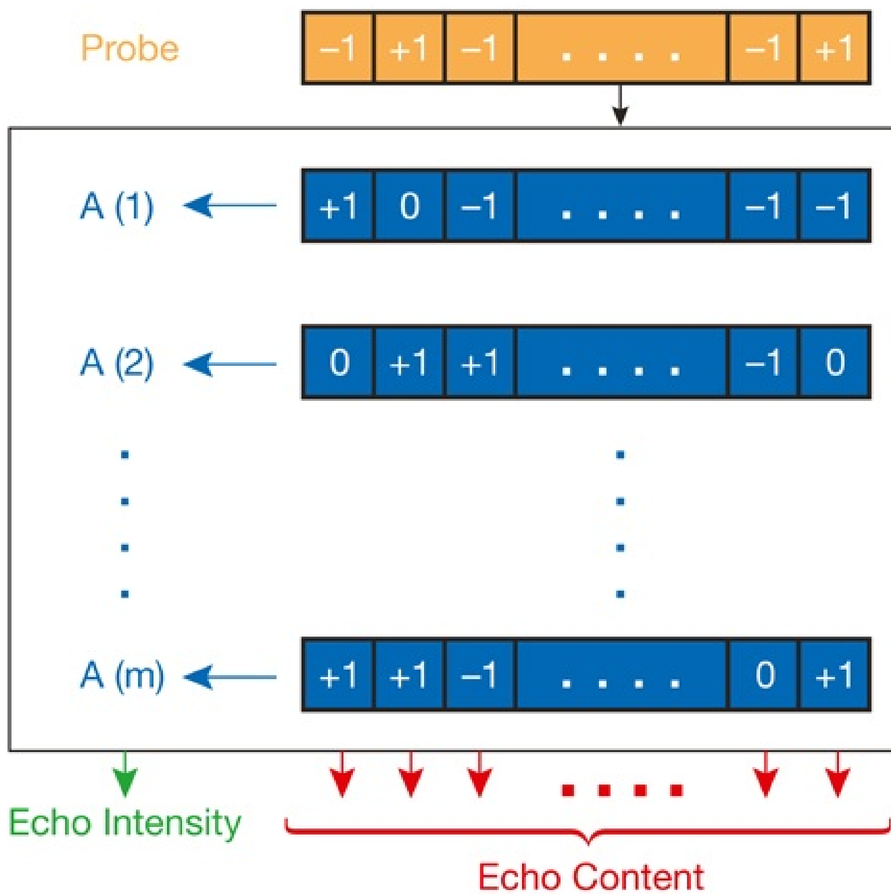

FIGURE 10.9 *Echo Intensity and Content in MINERVA 2*

Source: Hintzman, D. L. (1986). “Schema abstraction” in a multiple-trace memory model. *Psychological Review*, *93*, 411–428

The other aspect of an echo is **echo content**, which is the weighted average of the contents of all of the memory traces activated by the probe. Those memory traces with a greater overlap carry more weight and have a greater influence over the content of the echo. Thus, what is returned during retrieval is a composite or blending of many traces. Thus, MINERVA 2 can produce generalized effects in memory, such as the influence of schemas (Hintzman, 1986), without having to actually create and store schemas. This is because features of specific events get averaged out and what is left are the general abstract components. For example, if you are given the concept "grocery store," this activates all the memories about grocery stores that you have in long-term memory. What you remember is a weighted average of all of those grocery store experiences, with the individual contexts averaged out.

When people try to remember a single event, the precision of the memory cue is important. The more closely a memory trace corresponds to the cue, the larger the role it plays in the structure of the echo. But there is always some contribution of other overlapping traces, even if that contribution is weak. In this way, memory retrieval is always a distorting process. What is remembered is always a composite of several memories. To compound this distortion further, the echo that is returned is then stored as a memory trace. In this way, MINERVA 2 captures the idea that memory is constantly changing as a result of experience, and even by the act of remembering.

Although the MINERVA 2 retrieval process is constantly distorting, this same process also helps it narrow in on a memory trace. By using the echo that was returned to help focus the memory search, thereby activating a smaller and smaller set of memory traces, people can have more accurate retrieval compared to getting only the first returned, most averaged, memory trace. This process is shown in Figure 10.10. Initially, the composition of the echo only remotely resembles what is being searched for. However, over time, by using the echoes that were generated as part of the memory search process, the correspondence gets better and better.

Further Work

Work continues on models of memory. For example, **REM**, for **Retrieving Effectively from Memory** (Shiffrin & Steyvers, 1997), combines properties of SAM and MINERVA 2, as well as other sources, to provide a wider-ranging, more effective account of memory. Like SAM, REM assumes that information is stored in multiple memory traces and that memory is searched in a trace-by-trace, probabilistic fashion. Moreover, information is represented as a vector of features, like MINERVA 2. In addition, unlike other models, REM assumes that there is a probability of an error in the information stored in a memory trace. Work on the REM model has further inspired work on another model, **SARKAE**, which stands for **Storing And Retrieving Knowledge And Events**, which pushes these ideas further as a model of memory that can account for both specific knowledge of individual events or experiences, and more general knowledge that transcends the idiosyncrasies of singular experiences (Nelson & Shiffrin, 2013).

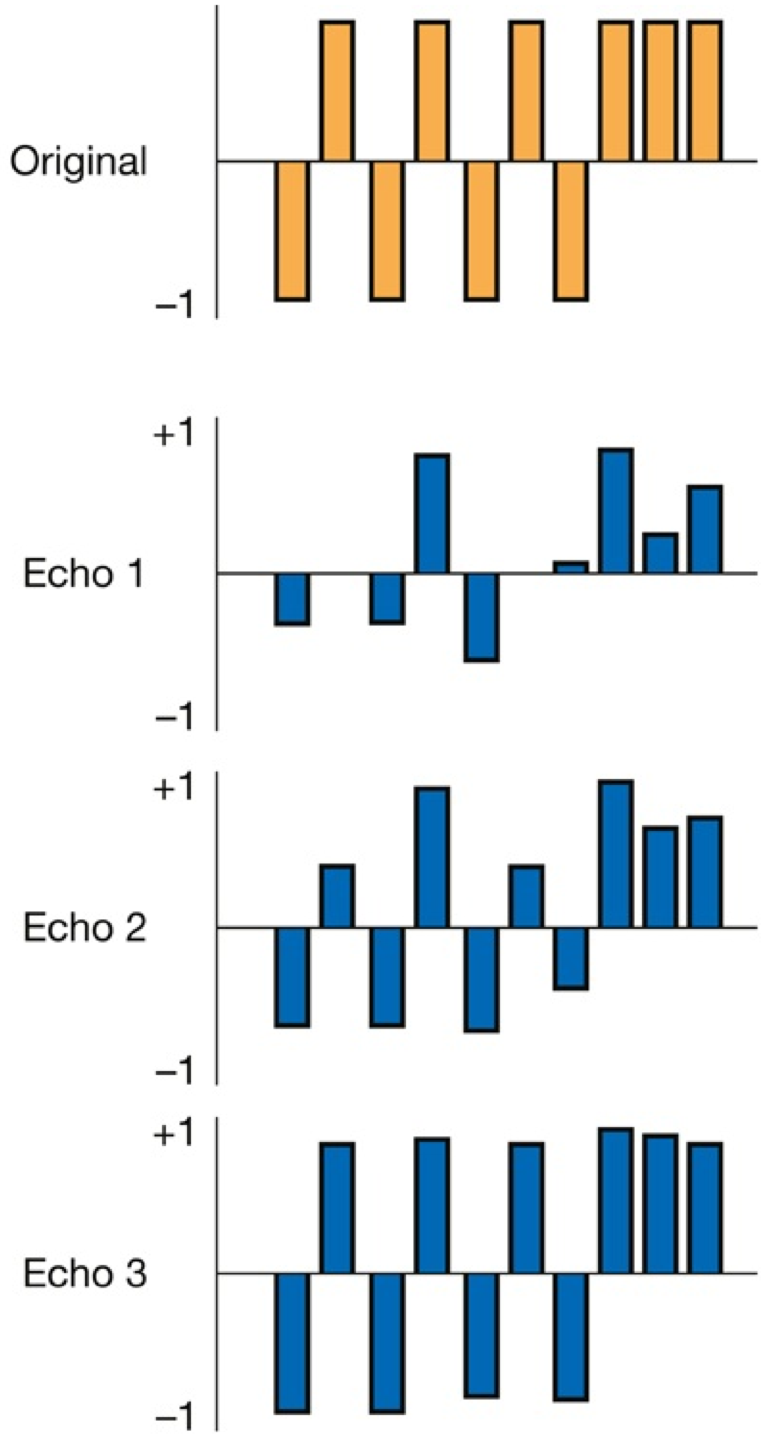

FIGURE 10.10 *Echo Improvement in MINERVA 2*

Source: Hintzman, D. L. (1986). "Schema abstraction" in a multiple-trace memory model. *Psychological Review*, *93*, 411–428

A feature that all of these models have in common is that they are exclusively activation models. That is, memory retrieval occurs only using the activation of memory traces. When a memory trace is no longer being actively processed, its activation decays to some baseline level. However, as you have read in other chapters, many memory researchers think that memory retrieval also involves the active suppression or inhibition of strong but inappropriate memory traces. The introduction of inhibitory processes in these sorts of models is rare but has been done, as with the **Hydrogen** model (Radvansky & Tamplin, 2013).

TODAM AND CHARM

Formal models like SAM and MINERVA 2 are multiple-trace models that store each experience separately in memory. Any blending of information occurs during retrieval. Now we consider two global matching models that involve distributed storage. This is sensible if one thinks about how the brain stores information. It is probably not a system where each experience is stored at a separate location in the cortex. Instead, many different memories are imposed on the same neural structure and the information is distributed throughout this structure.

Two of these models are **TODAM**, which stands for **Theory of Distributed Associative Memory** (Murdock, 1982a, 1982b, 1993), and **CHARM**, which stands for **Composite Holographic Associative Retrieval Model** (Eich, 1982, 1985). These models developed out of a verbal learning tradition to account for memory for item and associative information, as well as serial order information, with an emphasis on memory for paired associates.

These models, like MINERVA 2, assume that information is represented as vectors of features, with a different memory trace for each item. What is important here is that associative information is stored as a memory trace that is a convolution of the two item memory vectors. So, what’s a convolution? A convolution process is illustrated in Figure 10.11. Each item vector is combined with every element of the vector of another memory trace to create the composite vector trace. Thus, information from both items is distributed across a shared set of memory elements. This is actually an efficient way of encoding information about items and associations, using relatively few resources. Because of the regular structure of these convoluted vectors, the original traces can be extracted using a correlation process. The properties of the convoluted vector are correlated with the values of a memory probe, allowing for the extraction of the previous information.

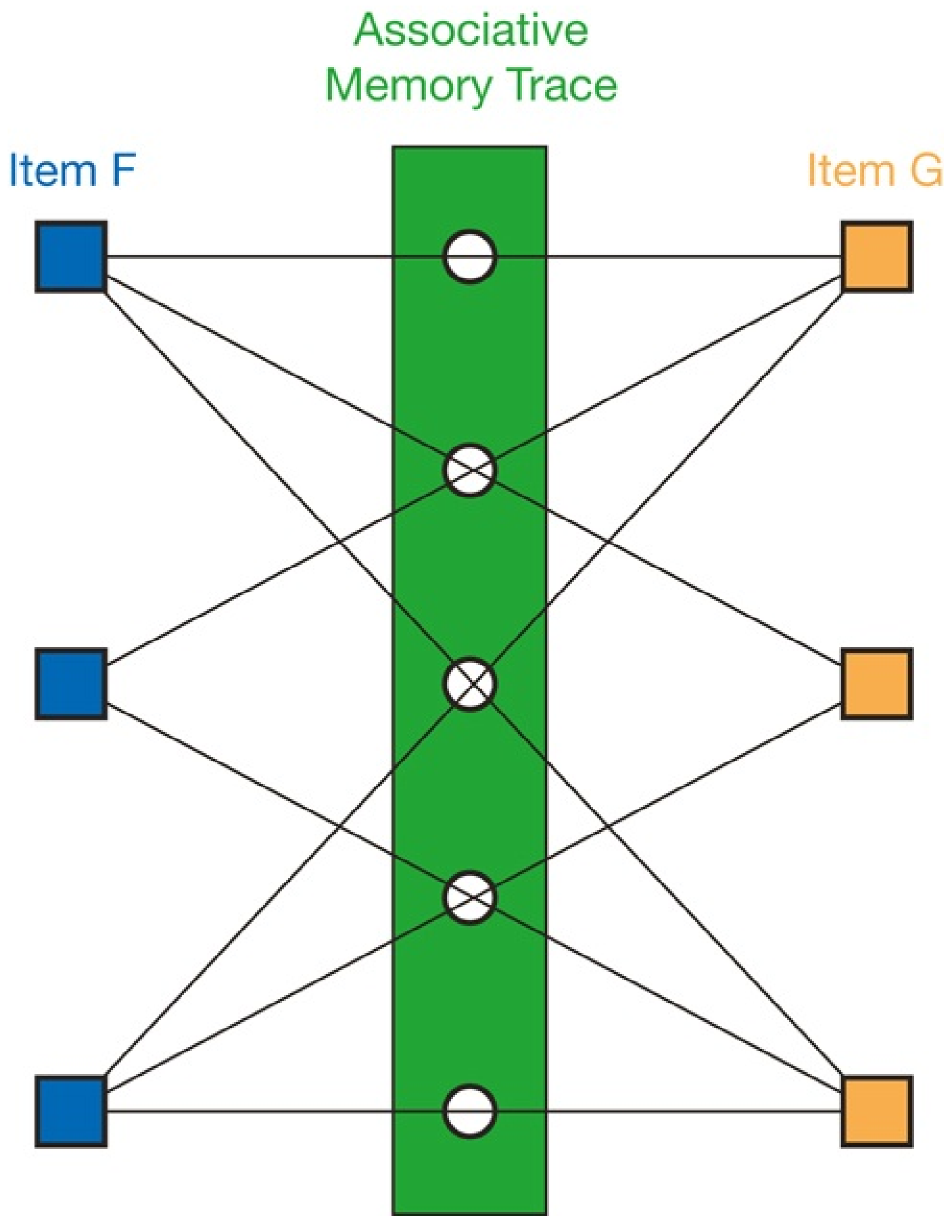

FIGURE 10.11 *Process of Convolution in Models like TODAM and CHARM*

Source: Eich, J. M. (1982). A composite holographic associative recall model. *Psychological Review*, *89*, 627–661

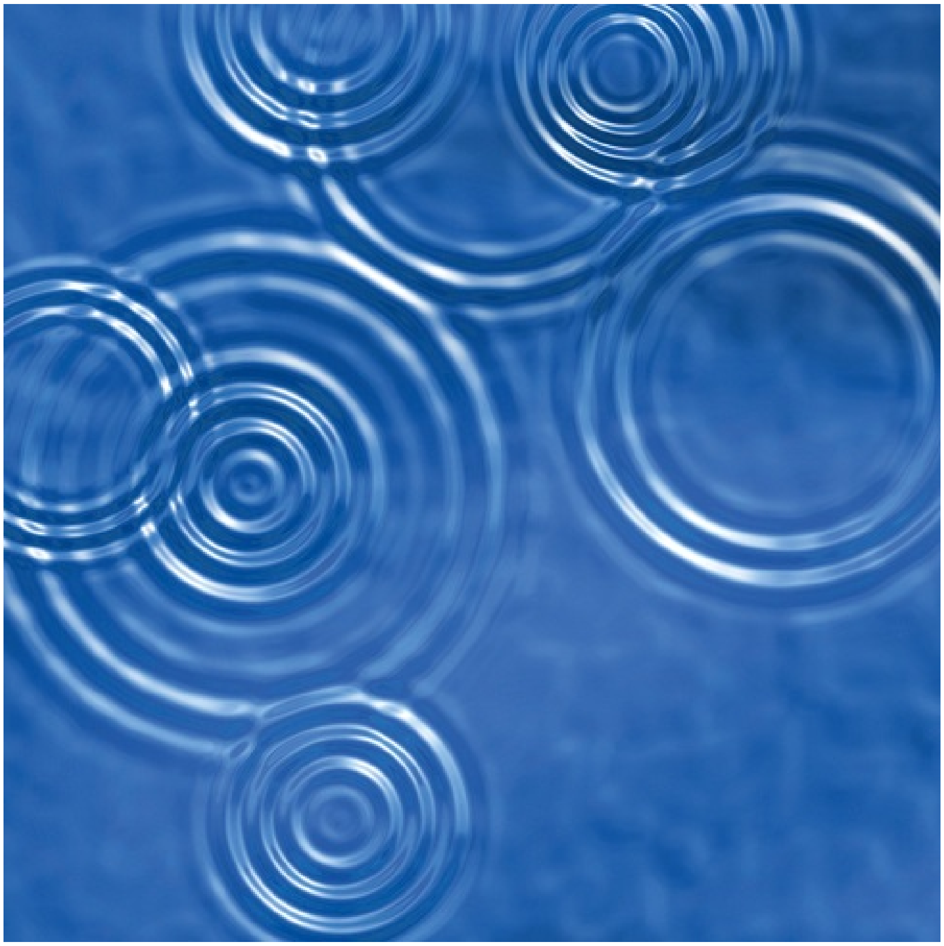

PHOTO 10.2 *Distributed storage global matching models of memory such as TODAM and CHARM assume that memories are laid out on the same structure, much like ripples overlay one another on water*

Source: DamianPalus/iStock/Thinkstock

One metaphor that has been used to describe this model is that of ripples on a pond (Murdock, 1982b). Different objects, such as a textbook, a computer, or a roommate, make different types of waves when thrown in the water. If a number of objects are thrown in the pond, all of the waves are superimposed on the same surface. With enough sophistication, one could examine the wave patterns to determine what objects were thrown in.

Stop and Review

Global matching models do not make strong assumptions about how information is organized. Instead, organization is more a result of the retrieval process. The SAM model is based on a probabilistic access of memory traces as a function of the match with the retrieval cue. Other models, such as MINERVA 2, account for how memory is changed by the act of remembering. More recent models include REM and SARKAE, which combine elements from different models. Still other global matching models, such as CHARM and TODAM, explore how multiple traces can be super-imposed on a limited representational structure, as would be expected with the neurons of the brain.

PARALLEL DISTRIBUTED PROCESSING (PDP) MODELS

An important point of models such as TODAM and CHARM is that memory traces are overlain on shared collections of neurons. The brain is only so big and the same neurons contribute to representing multiple memories. This basic idea has been elaborated on a grand scale for **parallel distributed processing**, or **PDP**, models (McClelland & Rumelhart, 1986; Rumelhart & McClelland, 1986).

These PDP models store information in a single structure, with multiple memories superimposed on one another in a common representational framework. This is done as a network of nodes and links like those in a semantic network. However, rather than a node being connected to those concepts that are associated with it, in a PDP model each node is massively interconnected with a very large number of other nodes. In many cases, memories are distributed across a number of shared components. In these models, individual nodes do not represent concepts. Instead, in a PDP model it is the pattern of activation that produces the representation, learning, and memory.

The most prevalent types of PDP models are what are called **connectionist models** or **neural networks**. These theories use the structure of the nervous system as their inspiration. The brain is, in a real sense, a distributed representation. Information is not stored in individual neurons. Instead, it is captured by the pattern of neural firing over large sets of neurons. So, any given neuron participates in the representation of a large number of different memories, along with what other neurons are doing. The number of theories using connectionist models is legion. These models are not only found in psychology but also in computer science, biology, and so on, because this is such a powerful means of representing and processing information.

A simple example of a connectionist network is shown in Figure 10.12. First, as you can see, there is a network of nodes and links. The model is basically a collection of "units" that are interconnected with other units (and potentially to themselves as well). The units in these models could correspond to neurons and the connections to axonal connections with other neurons. Again, this is different from the network models that were discussed earlier in this chapter in that a given node does not stand for a particular concept. It is just a node. These nodes are massively interconnected with other nodes, forming layers of nodes, similar to the layers of cells in the brain. Information is represented as a pattern of activation in the nodes of the network. These patterns are established by shifting the weights of the connections among the various nodes. Thus, learning is a shift in connection strengths, which allows new patterns to emerge.

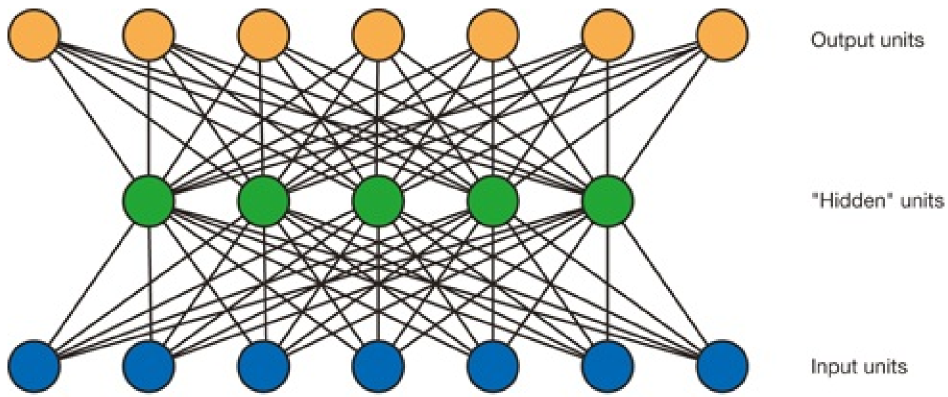

FIGURE 10.12 *Sample Parallel Distributed Processing Network*

As noted, these units are divided into "layers," which is consistent with the fact that brain cells are often grouped into layers along some paths of information processing. A typical connectionist model might contain three layers: an input layer, an output layer, and a "hidden" layer, whose presence allows for a great deal of flexibility in adjusting to experience.

Learning

Information is represented in connectionist models by the "strength" of the connections between the units. These strengths are called connection weights. Some of these connections are excitatory and some are inhibitory. This is similar to changing the strength of connections between neurons. Information in a PDP network is represented as the pattern of activated units. A model is operating well when the pattern of activity at the output stages bears a stable and consistent relationship to the pattern of information at the input stage.

The shifting of connection weights during learning is a gradual process. Every experience alters the neural connections in some way. Those that correspond to an experience become stronger, whereas the others may be weakened or not be affected at all. Over time, differences in the representation of different types of knowledge can emerge. Figure 10.13 shows shifts in the activation levels of a number of output nodes in a network that has been trained on a number of concepts. The more training there has been, the more differentiated the representations. Notice that concepts that have similar meanings are represented by similar patterns of activation. Thus, a connectionist model is able to capture memory characteristics such as semantic similarity.

The ability of connectionist networks to change and alter themselves rather fluidly is one of their biggest assets. It is also one of their biggest deficits. Specially, if a model is trained on a particular set of items it will learn those readily. That is, it will have a memory for those items. However, if the model is then trained up on a new set of items, without continued training on the old items, it will exhibit **catastrophic forgetting**. That is, the new pattern of connection weights will overwrite and destroy the old weights, causing the network to lose its prior knowledge (French, 1999; McCloskey, Cohen, 1989; Ratcliff, 1990). This is in contrast to human forgetting, which generally shows a much more gradual forgetting function. Thus, PDP models need to be developed in ways that allow for the long-term retention of knowledge along with flexible encoding of new information. This may be done by having both slow- and fast-adapting networks that work in tandem.

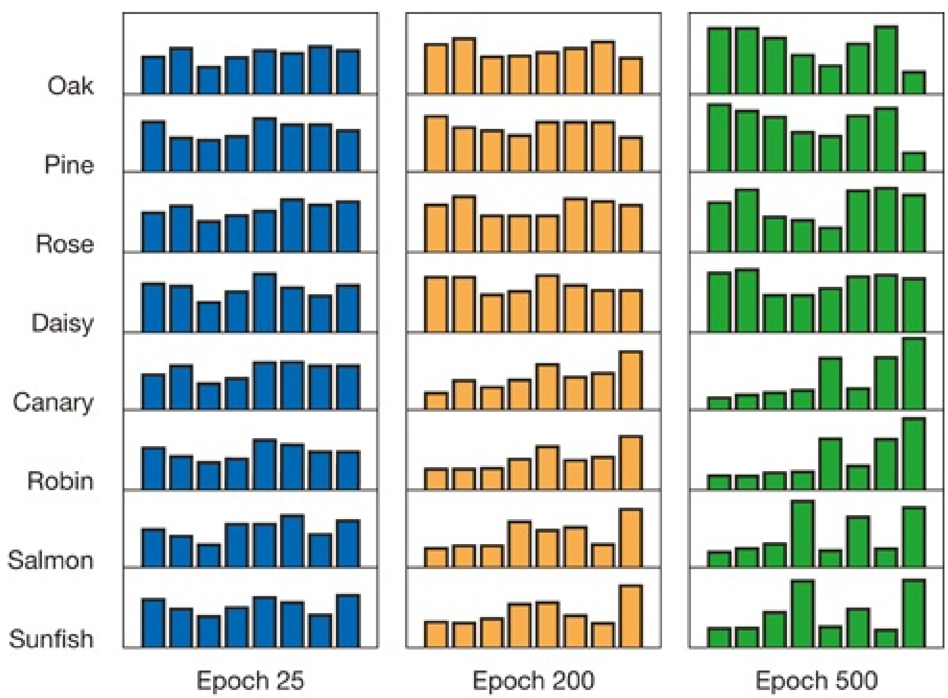

FIGURE 10.13 *Representational Improvement Across Various Epochs (Training Cycles) in a Parallel Distributed Processing Model—the Height of the Bars Corresponds to the Activation Level of a Set of Output Nodes for Each of the Concepts*

Source: McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: insights from the successes and failures of connectionist models of learning and memory. Psychological Review, 102(3), 419–457

Retrieval

After a memory is established in a PDP network, at some point it may be necessary to retrieve it. Norman, Newman, and Detre (2007) reported a PDP model that simulated the retrieval inhibition observed in a retrieval practice paradigm (see Chapter 8). This is a complex model in which there are separate networks for hippocampal (episodic) and cortical (semantic) memory systems, with (direct or indirect) recurrent connections among network elements for learning and which uses oscillating patterns of activity (akin to the cortical synchronization of theta waves). Using this model, Norman et al. simulated the pattern of results found with humans.

Stop and Review

PDP models are advanced and complex models. The way they process information is inspired by the organization and processing of neurons in the brain. Information is encoded in a complex of massively interconnected units by changing the pattern of connection weights between them. In PDP networks, there is a great deal of flexibility because any individual unit does not stand for anything. Information is represented and processed in a distributed fashion across the entire network.

DUAL PROCESS THEORIES

One characteristic of the models we have covered so far is that retrieval is a single process, possibly involving some version of a signal detection theory. However, there are other theories that take the view that retrieval involves **dual processes**. One is a **familiarity** process, which uses a signal detection-like principle in which information is identified as old (remembered) when it exceeds a threshold (like most formal models of memory). The other is a **recollection** process that involves the conscious retrieval of components that are associated with the to-be-retrieved information (Mandler, 2008; Yonelinas, 2002). Both of these typically work together but we sometimes find ourselves in situations where one process produces one result and the other produces another (but see Donaldson 1996; Rotello & McMillan, 2006). For example, suppose you meet someone who seems familiar but you cannot remember his or her name or how you know him or her. This is remembering using familiarity but not recollection.

Atkinson and Juola

One of the earliest dual process models was Atkinson and Juola's (1973, 1974) model. According to this view, people first try a fast, familiarity process to see if information is recognized. If this initial process fails, then a more deliberate and effortful search is made of long-term memory. This more effortful search produces a richer set of knowledge that is associated with recollection. Thus, in this model, recollection is conditional on familiarity failure.

Recent Views

Subsequent dual process theories assume that recollection and familiarity operate concurrently (Mandler, 1980). Because familiarity uses less information, it often finishes before recollection. Moreover, familiarity is more unconscious and automatic, whereas recollection is more conscious and effortful (Jacoby, 1991). Also, familiarity provides more quantitative information about the strength of the memory trace(s). In comparison, recollection provides more qualitative features associated with the information (e.g., who? what? where? when? why?) (Yonelinas, 2002). It has also been suggested that there may be three processes available for memory retrieval, namely familiarity, recollection, and reconstruction (Brainerd, Reyna, & Howe, 2009).

Improving Your Memory

The primary purpose of constructing formal models of memory is to allow memory researchers to better predict how memory will perform under various conditions. This is because our intuitions and mental reasoning can often be wrong. The same is true for your own assessment of how your memory works and when it will and will not be effective. Additionally, formal models give an idea about what you can do to improve your memory. Specifically, when you are trying to learn some new information for a class, your job, or some other aspect of your life, try to keep track of your time and how much you are learning. Count up how much you can remember later. Then, over time, plot your performance and look to see how you have done. Having a more solid base on which to understand your own performance, rather than relying exclusively on your intuition, should help you to more effectively budget your time so that you come out ahead when it is time to demonstrate or use the knowledge.

One Process or Two?

One of the rules of thumb in science is, when all else is equal, accept the simplest solution. This principle is **Occam's razor**. The idea is to trim out all of the irrelevant stuff. So, why have a dual process theory of memory if a single process model will do just fine? Well, one reason is that recollection and familiarity seem to be doubly dissociated. That is, there are things that affect one process more than the other, and vice versa. For example, recollection is more influenced than familiarity by (1) different levels of processing, (2) generation effects, and (3) full versus divided attention during learning or retrieval. In contrast, familiarity is more affected than recollection by (1) changes in modality (e.g., first hearing something (auditory) and then later reading it (visual)), (2) perceptual priming, (3) changing response bias (i.e., being more liberal or conservative), (4) familiarity information being forgotten more rapidly (Yonelinas, 2002), and (5) the influence of novelty (Kishiyama & Yonelinas, 2003).

Moreover, familiarity and recollection involve different neurological structures. Familiarity depends more on the temporal cortex surrounding the hippocampus and on the operations of the cortex as a whole. Thus, brain damage typically has a smaller effect on familiarity than on recollection. In contrast, recollection depends more on the hippocampus itself and the frontal lobes. The influence of the hippocampus is seen in amnesics who have hippocampal damage. The influence of the frontal lobes on recollection is also seen in older adults who have age-related changes in frontal lobe functioning. Similar results are observed in people who have sustained frontal lobe damage (Yonelinas, 2002). So, given this sort of double dissociation, a theory that includes both processes is needed.

Stop and Review

It is possible that memory retrieval involves dual processes, as suggested by Atkinson and Juola. This typically involves a simpler, automatic, familiarity-based process and a more complex, deliberative, conscious recollection-based process. Evidence for dual process theories comes from work showing double dissociations.

PUTTING IT ALL TOGETHER

To best understand memory, you should be able to make reasonably precise predictions about how it works under different conditions. This is best done using formal models of memory. Some of these models assume that memory retrieval largely involves a single process, such as the threshold model; semantic network models, which describe the structure of memory using associative relations among concepts and the spread of activation among them; latent semantic analysis of large amounts of input data with a large number of dimensions; multiple-trace models (SAM and MINERVA 2); distributed storage models (TODAM and CHARM); and PDP models, which use the structure of the nervous system for inspiration. Other models involve a complex of multiple processes, as with the generate–recognize model, the ACT model with its propositional network and production memory, and dual process models of memory that assume that there are at least two memory processes operating during retrieval: a familiarity component and a recollection component. Whichever approach is taken, the overarching goal is bring a greater degree of understanding and precision to our approach to what goes right and wrong with human memory.

STUDY QUESTIONS

1. What are two simple models of recognition and recall? What evidence is there to suggest that such basic ideas may be in error?
2. How is signal detection theory related to threshold models of memory?
3. What were some of the first network models of memory and how did they structure information?
4. By what processes are memories retrieved from or activated in a network model of memory?
5. In what ways is LSA similar to and different from more tradition network

models of memory?
6. What are the primary characteristics of global matching models of memory?
7. What are some of the ways that information is thought to be stored and retrieved in global matching models?
8. What is the difference between multiple-trace and distributed representation models of global matching models of memory?
9. What are some of the major features of PDP models of memory?
10. What are the two types of processes that are operating in dual process models? What evidence supports this idea?

KEY TERMS

- ACT
- catastrophic forgetting
- CHARM
- Collins and Quillian's network model
- connectionist models
- correct for guessing
- correct rejection
- distributed storage models
- dual processes
- echo
- echo content
- echo intensity
- false alarm
- familiarity
- formal model
- generate–recognize model
- global matching models
- hit
- Hydrogen model
- links
- LSA
- MINERVA 2
- miss

- multiple-trace models
- network theory
- neural networks
- nodes
- Occam's razor
- PDP
- priming
- production memories
- propositional network
- recall
- recognition
- recognition failure
- recollection
- REM
- SAM
- SARKAE
- signal detection theory
- spreading activation
- threshold model
- TODAM
- token nodes
- Tulving–Wiseman function
- type nodes

EXPLORE MORE

Here are some additional readings to allow you to explore issues more deeply concerning formal models of memory.

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CHAPTER 11

Memory for Space and Time

Space and time. For physicists, this is the fabric of reality. Psychologically, these are the primary dimensions for orienting ourselves in our world. Space and time provide the framework for the events that we experience and remember. Spatial information is where different entities in the world are located and how they are oriented with respect to one another. This is important when people navigate, locate objects, estimate distances, and so on. In this chapter we look at how memory for spatial configurations corresponds to physical layouts and what distorts memory for space. In general, space is a relatively static dimension of reality. We can move from one place to another and back again with ease and with little change in the spaces themselves. In contrast, temporal information is for when events occurred, with respect to the present, to other events in the past, and even to a standard time scale, such as a calendar. Unlike spatial location, our place in time is always, inexorably, being pushed forward. We can't go back.

This chapter addresses memory for space (where things are), and time (when things happened). Starting with spatial memory, we cover issues relating to memory psychophysics or how memory for space corresponds to actual, measured spatial reality. This is followed by a consideration of the properties of mental maps and how these may be created using spatial and other information. Then we address memory for time, such as how temporal information is stored in and retrieved from memory, influencing how accurate we are in locating events in time. A number of theories are considered for how people derive estimates of when things happened.

MEMORY FOR SPACE

Although space may be the final frontier in science fiction, it is far from that in memory research. There have been many studies of spatial memory. In fact, the study of memory and space in research with rats helped bring an end to radical behaviorist views in psychology (Tolman, 1948). One appeal of spatial knowledge is that it is easy to understand exactly what is present in the world. We can explicitly measure distances, areas, curvatures, and so forth. We can then directly compare these measurements to memory of these spatial properties.

Neurologically we can see the specialization and complexity of spatial memory. For example, single-cell recordings of the hippocampus and related areas have shown that parts of these areas are important for knowing spatial locations (Burgess, 2002; Muller, Kuble, & Ranck, 1987; Shapiro, Tanila, & Eichenbaum, 1997). This includes the discovery of groups of neurons that are specialized for processing spatial information, such as place cells (O'Keefe, & Dostrovsky, 1971), grid cells (Hafting, Fyhn, Molden., Moser, & Moser, 2005), and boundary cells (Lever, Burton, Jeewajee, O'Keefe, & Burgess, 2009), as described in Chapter 2. Moreover, fMRI studies with humans show evidence of a region, the parahippocampal place area (BA 36), that is critical for understanding the spatial structure (Epstein & Kanwisher, 1998) and that can disrupt spatial learning if it is damaged (Epstein et al., 2001)

Moreover, spatial memory is tied up in many of the phenomena that affect memory more generally. For example, people better remember the spatial location of pictures when they are emotionally arousing (Mather & Nesmith, 2008). This part of the chapter discusses how spatial information relates to memory for a space by covering memory psychophysics, memory for information learned from maps, and how our interaction with the world affects spatial memory.

Memory Psychophysics

How well do our memories for space correspond to actual spaces? The part of psychology that deals with how our experience of the world corresponds to physical properties is **psychophysics**. The question addressed by psychophysics is how does our experience of reality correspond to actual reality? Many psychophysicists study issues of sensation and perception and have established some "laws" of psychophysical relations. One example is **Stevens's Law** of psychological magnitude (Stevens & Galantner, 1957). For this law, the relation between actual and perceived magnitudes is a power function that is captured by the formula $\Psi = k\phi^n$. Here, Ψ corresponds to psychological magnitude. This psychological experience is related to the actual physical magnitude, ϕ, raised to a power, n, and modified by a constant, k.

The important point here is that the same principles can be used to study memory. This is memory psychophysics (Algom, 1992). Memory psychophysics has been applied to a number of domains, including memory for size, area, loudness, and labor pains (Algom & Lubel, 1994; Algom, Wolf, & Bergman, 1985; Chew & Richardson, 1980; Kerst & Howard, 1978, 1983; Moyer et al., 1977). Here, we consider memory psychophysics for spatial properties, such as distance and area.

The relation between actual and perceived spatial distance is fairly good. The exponent in Stevens's Law is close to 1, which means that our perceptual experience of space is a near perfect one-to-one relationship. As for our memory of space, such as distance, the relation is still good but there are noticeable distortions (Wiest & Bell, 1985). This distortion is less when the space was originally viewed all at once compared to when it was inferred from memory from separate experiences (e.g., estimating distances between buildings that are separated by other buildings, so the actual distance cannot be viewed directly).

One theory of memory psychophysics of space is of the fuzzy trace variety. This is the **category adjustment theory** (Huttenlocher, Hedges, & Duncan, 1991). For this view, performance is a combination of both fine-grained and coarse-grained memories. Objects in space are located within regions that serve as categories or schemas. Thus, people remember the object itself as well as the category to which it belongs. For example, if you are trying to remember where a certain city is located in the country, you may have a fine-grained memory of the actual location of the city on a map, as well as a coarse-grained categorical memory of the area it is in, such as which state it is in. Memory for space is always a combination of these two influences.

These two sources of spatial knowledge vary in their relative contribution at any given occasion. The more influence the fine-grained memories have during retrieval, the weaker the influence of the coarse-grained memories (Sampaio & Wang, 2008) and vice versa (Kemp, 1988). When a space has clear and obvious boundaries, the coarse-grained categorical information can have an immediate influence; however, when the borders and regions are more subtle, such as on a college campus, the influence of such regions on spatial memory can be delayed until knowledge and familiarity build up to a certain level (Uttal, Friedman, Hand, & Warren, 2010).

TRY IT OUT

This Try It Out section explores memory for distances using psychophysics. For this task, first set up 12–36 displays of objects at different distances (although you can use area, angles, or something else if you want). One way to do this is to have pairs of small pictures of objects on pieces of paper. Another is to have a variety of objects at different distances from your participants.

Have people estimate those distances. If you have objects on pieces of paper, have people estimate the distances between them in either inches or centimeters. If you use objects in the real word, have people estimate the distances from where they are standing, in feet or meters, to the objects. It does not matter how accurate people are in terms of what they think an inch or a meter is, so long as they are consistent with themselves.

You should have 12 or more participants. Collect this data under two conditions. In one have the people estimate the distances from *perception*—that is, as they are looking at the distance. In the other condition have people estimate the distances from *memory*—that is have them look at the distance, then either remove it or have them turn away, and then have them estimate the distance. The objects for the perception and memory conditions should be different.

After you have collected the data, plot the participants' estimates against the actual distances. For each person, derive an estimate of the slope for the function that best fits those points for each condition. What you should find is that the slope of the function will be smaller in the memory condition than the perception condition, illustrating some compression in spatial memory.

Stop and Review

Memory for space is generally pretty good. This assessment can be done using principles from psychophysics, such as Stevens's Law. There does appear to be some compression of spatial distances in memory. Overall, consistent with the category adjustment model, spatial memory is a combination of more fine-grained, metric memories along with more coarse-grained, categorical memories.

Mental Maps

Of course, memory for space is more complex than just remembering distances. People create complex mental representations to guide their travels around the house, through town, and across the country. This section looks at how mental maps are represented and used in memory. First, we consider what are called **spatial theories** because they assume that mental maps are structured according to the same structure as is space. For such views, mental maps are second-order isomorphs (Shepard & Chipman, 1970). That is, a mental map would functionally capture the structure of a real map, although, neurologically, there is no one-to-one relationship between the two (which would be a first-order isomorph). For example, a clock is a second-order isomorph of the daily rotation of the earth (by capturing this regular temporal quality), but a model of the solar system in which the earth spins each day is a first-order isomorph.

This aspect of spatial theories of mental maps makes them straightforward to understand. The simplest version is that a mental map corresponds directly to the space it represents. This is a **metric view**. Given the results in memory psychophysics studies, this seems reasonable. However, there have been few serious metric theories (Levine, Jankovic, & Palij, 1982) because mental maps are almost always distorted in some way.

A major influence on mental maps is areas or regions. Space is not uniform. The world is divided into continents, continents are (often) divided into countries, countries are divided into states or provinces, and so on. There are many ways that we chop up space. Locations are often assigned to superordinate locations or regions. The **hierarchical view** (Stevens & Coupe, 1978) is that mental maps are organized the same way. Figure 11.1 gives an example of a hierarchical representation of cities in Colorado and Ohio. This spatial hierarchy reflects the organization of smaller areas into larger ones and can lead people to make errors. When people estimate the direction between two locations, these estimates may be in error if the actual direction is different from the relation between the hierarchical regions. An example of this is shown in Figure 11.2. People often mistakenly report that San Diego, CA, is west of Reno, NV, because California is generally west of Nevada. However, Reno is actually farther west than San Diego. Thus, the direction of the superordinate regions influences spatial memory. This is found not only for very large spatial structures such as cities and states but also for smaller environments such as neighborhoods, with people making more directional errors across neighborhoods than within (Han & Becker, 2014).

A mental map based strictly on spatial regions would be categorical, that is, all of the locations within a region could be considered to be more or less the same, but this is not the case. A theory of mental maps that uses a combination of metric and region information is a **partially hierarchical view** (McNamara, 1986). Some of the best evidence for this comes from spatial priming studies in which people first memorized a map that was divided into regions. Within each region were a set of locations, such as cities or objects (see Figure 11.3). After memorization, people were given a primed recognition test. That is, a series of location names was given and the task was to indicate whether those names were on the map. Priming was assessed using response times to the target object as a function of the spatial proximity of the prime object. In general, mental map locations prime one another (McNamara, 1986). An example of such priming is shown in Figure 11.4. There is more priming (people are faster) for close locations (e.g., *Fairview* and *Avon* in Figure 11.3) than for far locations (e.g., *Casper* and *Needles*). Moreover, regions mediate the amount of priming. For example, keeping Euclidean distance the same, there is less priming across regions (e.g., *Bordmann* and *Stapleton*) than within a region (e.g., *Fairview* and *Avon*).

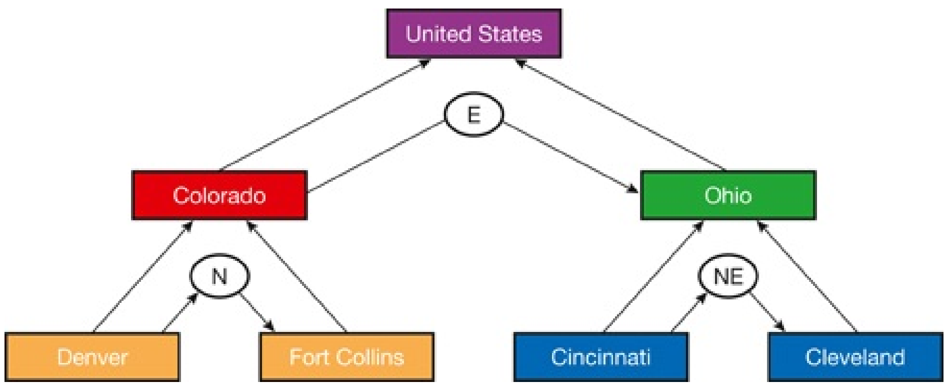

FIGURE 11.1 *Hierarchical Representation of Space*

Adapted from: Stevens, A., & Coupe, P. (1978). Distortions in judged spatial relations. *Cognitive Psychology*, *10*, 422–437

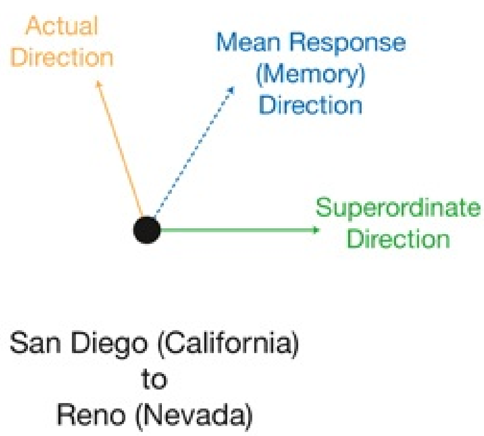

FIGURE 11.2 *Distortion of Direction Judgments as Influenced by Superordinate Regions*

Adapted from data reported by: Stevens, A., & Coupe, P. (1978). Distortions in judged spatial relations. *Cognitive Psychology*, *10*, 422–437

As a real-world example, some Germans overestimate distances between cities in the former East and West Germany, even though the country is now united (Carbon & Leder, 2005). Moreover, the more negative their opinion of reunification (i.e., the more salient the East–West differences were in their minds), the greater the overestimation.[1] This increased perceived distance is also observed in virtual environments, when the space is perceptually experienced either as a single large space or divided into separate regions by walls coming partially out from the sides (forming a wide doorway from one "space" to the next). The more perceived (but not actual) boundaries there were between a person and a target location, the greater the reported distance (Sturz & Bodily, 2016). Thus, this partially hierarchical influence is observed even when the region divisions are subjective rather than objective (McNamara, Hardy, & Hirtle, 1989).

FIGURE 11.3 *Map Used in Spatial Priming Studies*

Adapted from: McNamara, T. P. (1986). Mental representations of spatial relations. *Cognitive Psychology*, *18*, 87–121

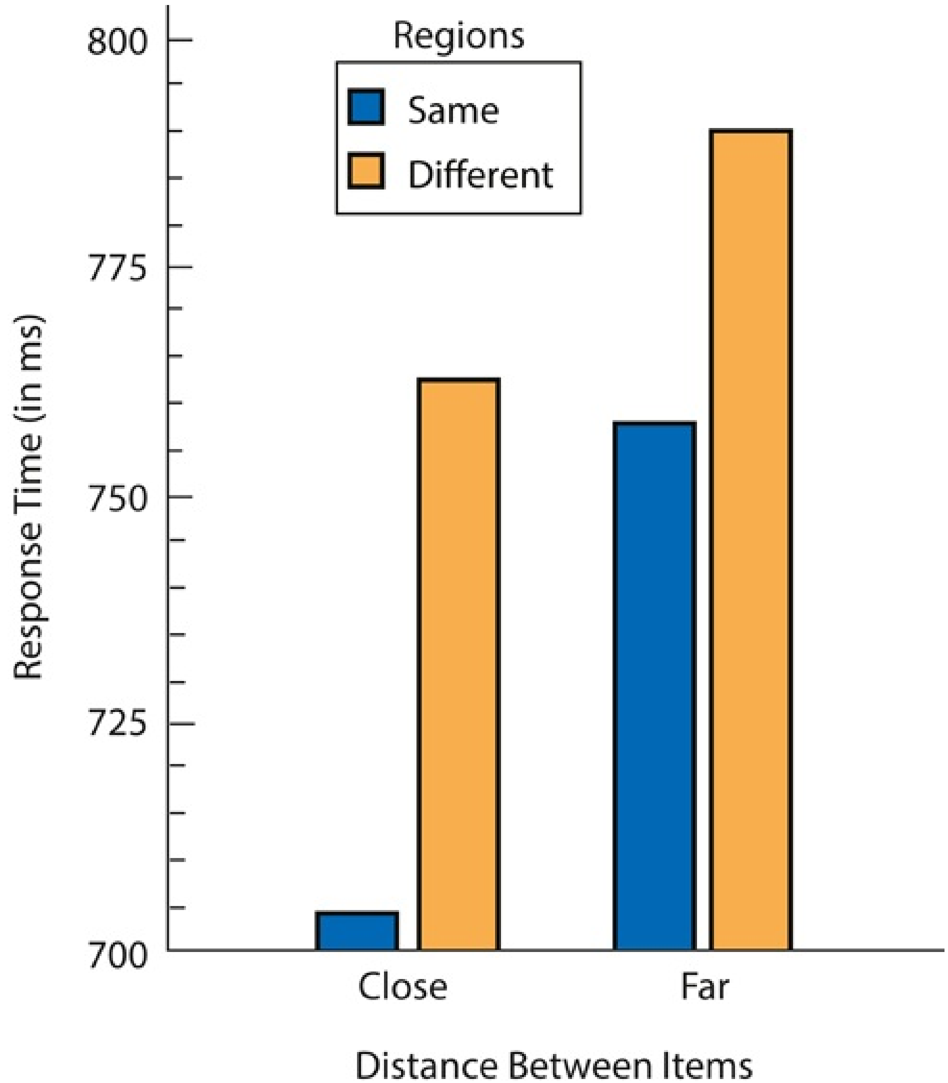

FIGURE 11.4 *Response Times to Probes as a Function of Route Distance*

Adapted from: McNamara, T. P. (1986). Mental representations of spatial relations. *Cognitive Psychology*, *18*, 87–121

The influence of spatial borders applies not only to spatial memory but also to thinking and decision-making about spaces. In a study by Mishra and Mishra (2010), students at the University of Utah were asked to make decisions about which of two locations they would prefer to purchase a vacation home. This could be in either the state of Oregon or the state of Washington. Some students were told that an earthquake had occurred 200 miles from both of the potential vacation sites. For half of the students, the earthquake was centered in Oregon and for the others it was centered in Washington. What was observed was that students showed a marked preference for the vacation home in the state that did not have the earthquake centered in it, even though the distance to the earthquake centered was the same and earthquakes don’t really care about political borders.

Also consistent with a partially hierarchical view is geographical knowledge of the locations of cities (Friedman & Brown, 2000; Friedman, Brown, & McGaffey, 2002), which is often clustered based on political/climatic regions. As shown in Figure 11.5, when University of Alberta students were asked to estimate the latitude of North American cities four categories emerged. These were Canada, the northern United States, the southern United States, and Mexico (with Miami floating in between the United States and Mexico). This occurs even when people are given supporting information, such as map outline (Friedman, 2009). A similar result was observed for students from Southwest Texas State University (Friedman, Kerkman, & Brown, 2002) and for students from Universidad Autónoma de Tamaulipas in Mexico (Friedman, Kerkman, Brown, Stea, & Cappello, 2005). So, where people live is less important than how they mentally divide up the world. Figure 11.5 also shows a similar categorical grouping for European cities. This prior knowledge of the world is important as these biases are not observed if maps of imaginary places are used (Newcombe & Chiang, 2007).

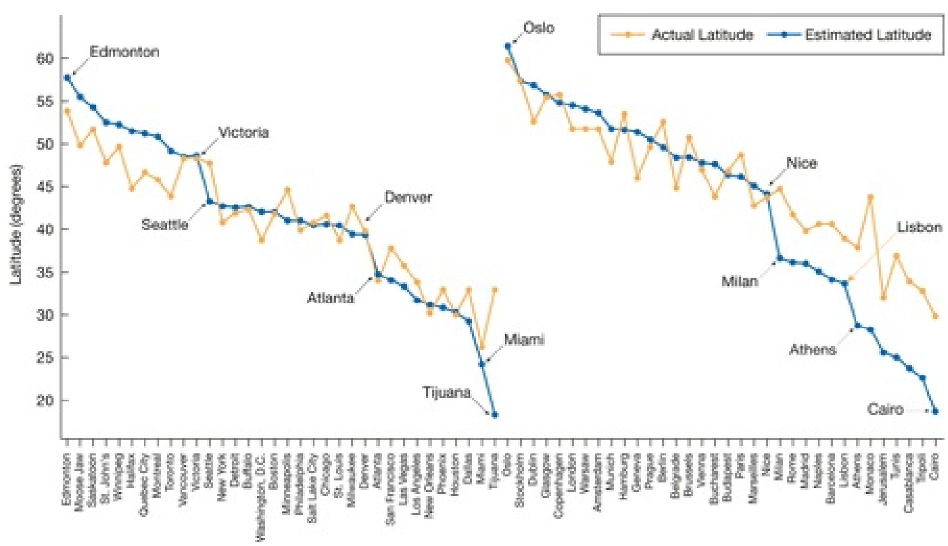

FIGURE 11.5 *Influence of Geographical Regions on Latitude Estimations in North America and Europe/Africa*

Source: Friedman, A., & Brown, N. R. (2000a). Reasoning about geography. *Journal of Experimental Psychology: General*, *129*, 193–219

Other spatial characteristics can influence mental maps. One is the number of intervening locations on a **route** between two locations. The more locations on a route, the longer is the estimated distances (Thorndyke, 1981). This increased crowding causes that part of the mental map to “expand” to accommodate all of the places. In one study, people memorized a map like the one in Figure 11.6. In this map there are varying numbers of intervening locations between two cities. When memory was tested by having people estimate the distances between pairs of cities, the more intervening cities there were, the greater the distance estimates (see Figure 11.7).

Route distance can also influence memory (McNamara, Ratcliff, & McKoon, 1984). Given the same Euclidean distance, priming is reduced if there is a long, circuitous route between two locations compared to if there is a short and direct one. In one study, students memorized maps like the one in Figure 11.8. The primed recognition test that followed had conditions in which map locations were close in both Euclidean and route distance (e.g., Emmet & Davis), far in both Euclidean and route distance (e.g., Anderson & Berthold), or close in Euclidean distance but far in route distance (e.g., Mantee & Foster). As can be seen in Figure 11.9, if the two locations were far along the route, even if they were spatially close, they were perceived as spatially far apart.

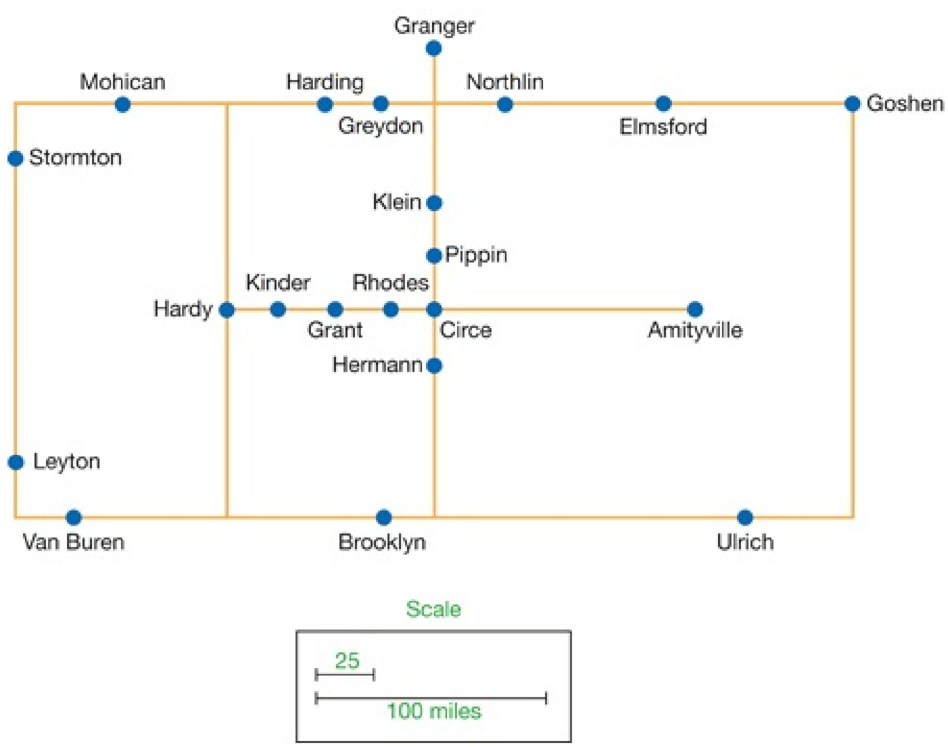

FIGURE 11.6 *Map of Fictitious Area That Varies the Number of Intervening Locations Between Cities but Keeps the Distance Relatively Constant*

Adapted from: Thorndyke, P. W. (1981). Distance estimation from cognitive maps. *Cognitive Psychology*, *13*, 526–550

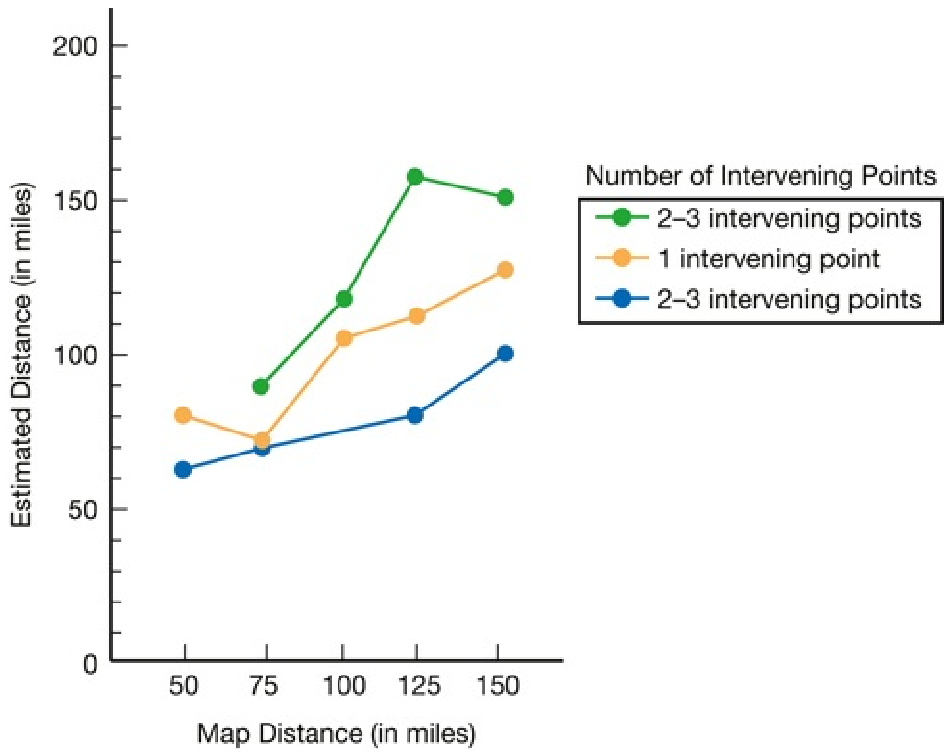

FIGURE 11.7 *Distance Estimate Results as a Function of the Number of Intervening Cities*

Adapted from: Thorndyke, P. W. (1981). Distance estimation from cognitive maps. *Cognitive Psychology*, *13*, 526–550

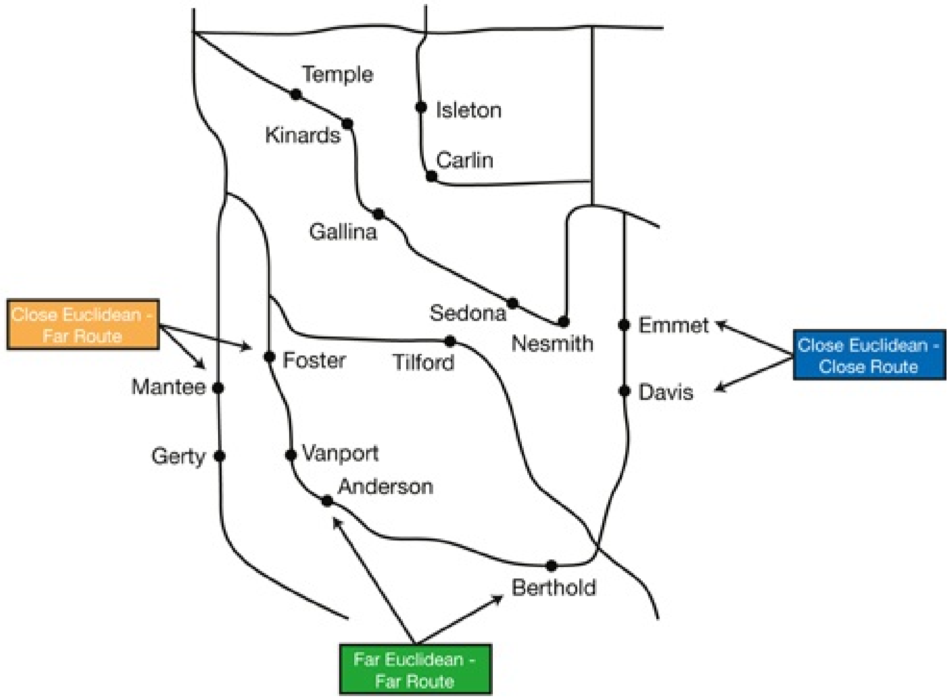

FIGURE 11.8 *Map Used to Study the Effects of Spatial and Route Distance on Spatial Memory*

Source: McNamara, T. P., Ratcliff, R., & McKoon, G. (1984). The mental representation of knowledge acquired from maps. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *10*, 723–732

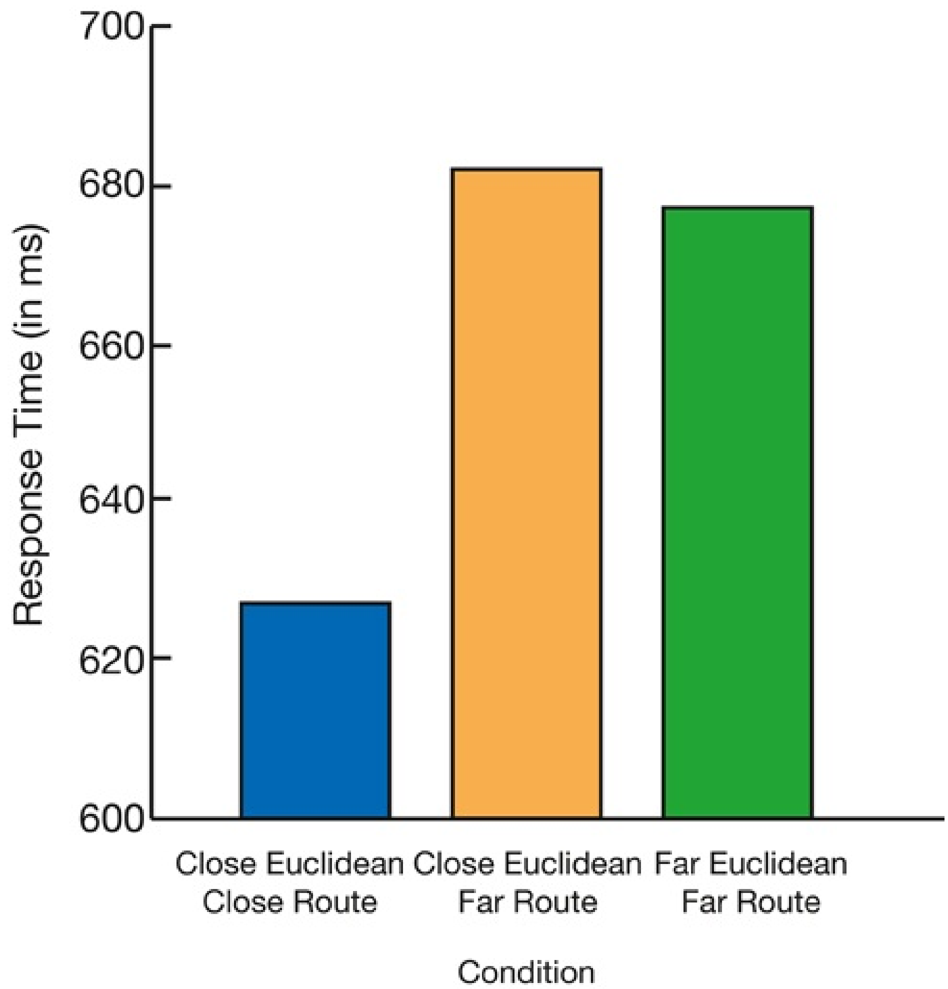

FIGURE 11.9 *Spatial Priming as Affected by Both Euclidean and Route Distance*

Derived from data reported in: McNamara, T. P., Ratcliff, R., & McKoon, G. (1984). The mental representation of knowledge acquired from maps. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *10*, 723–732

Mental maps are affected not only by spatial characteristics but also by the temporal order or sequence in which map items are learned. For **temporal theories**, places can be either close or far in temporal proximity in much the same way that they can be close or far in spatial proximity. Typically, spatial and temporal proximity are confounded during learning. Locations that are close in space are also experienced close in time. However, these two dimensions can be disassociated. For example, imagine people learn the simple map in Figure 11.10 in the order indicated by the arrows. Although people can derive spatial qualities (such as direction and distance) from their mental map, evidence from priming measures suggests that temporal, and not spatial, structure is the primary basis for the mental map (Clayton & Habibi, 1991; Curiel & Radvansky, 1998).

This influence of temporal order for mental maps varies. **Hybrid theories** assume a contribution of both spatial and temporal information. For example, in a study by Curiel and Radvansky (1998), during memorization people either named indicated locations (focusing on identity information) or pointed to named locations (focusing on spatial information). As shown in Table 11.1, there was more temporal priming when people named the location but more spatial priming when they pointed to the location. So, how people lean maps can have a dramatic influence. Spatial and temporal information can work together to influence mental map structure (McNamara, Halpin, & Hardy, 1992b). Learning map locations that are close together in both time and space provides the greatest benefit to memory.

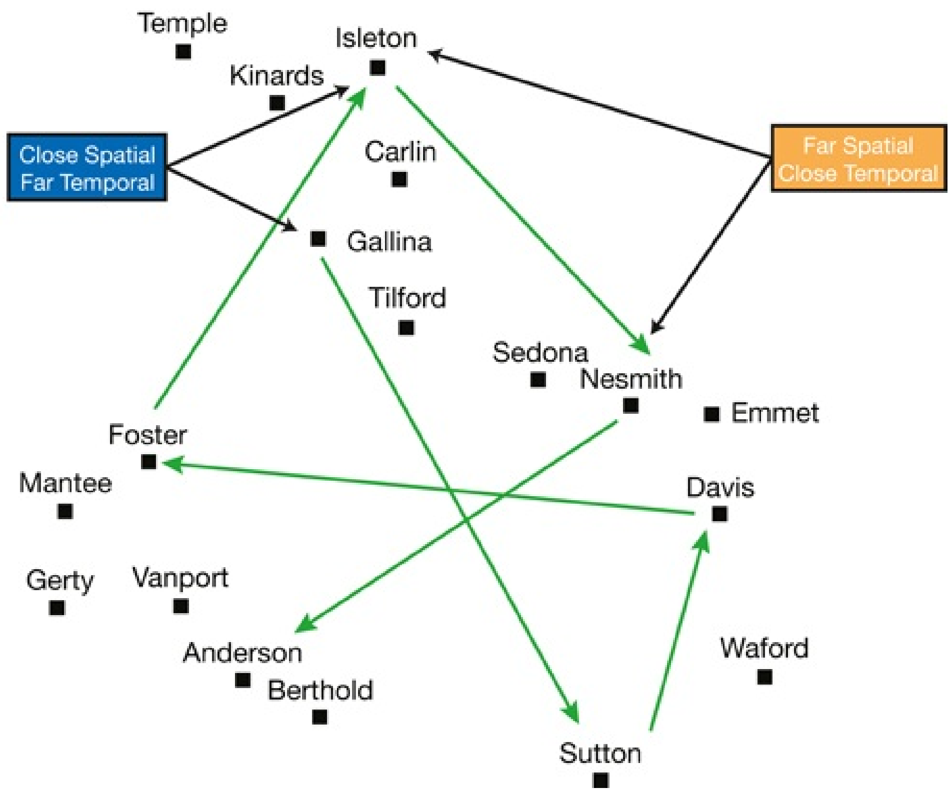

FIGURE 11.10 *Fictitious Map Illustrating the Deconfounding of Spatial and Temporal Proximity With a Partial Temporal Order Indicated by the Arrows*

Adapted from: Clayton, K., & Habibi, A. (1991). Contributions of temporal contiguity to the spatial priming effect. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *17*, 263–271

TABLE 11.1 *Differences in Spatial and Temporal Priming: Whether People*

Name Map Locations during Learning in Response to Location Cues or Point to Map Locations in Response to Name Cues

Condition	Naming	Pointing
Spatial		
Close	690	681
Far	714	730
Priming	24	49
Temporal		
Close	669	721
Far	709	718
Priming	40	−3

Source: Curiel & Radvansky (1998)

Improving Your Memory

Our memories for space are not like mental images that can be treated like one is viewing a picture. Instead, they are divided into regions, and these regions affect our use of these mental maps. When learning a new space, it is best not to try to strive against this bias. This is just how our memories work. To make the learning of a space faster, so that you can use it and navigate in it more effectively, look for a way of dividing the large space into smaller regions. Then, try to learn the locations of individual things within each region. This is another example of chunking in memory.

Mental maps also reflect **semantic relationships**. The degree to which different locations are meaningfully similar can accentuate priming, particularly if those places are already near one another (McNamara, Halpin, & Hardy, 1992a; McNamara & LeSueur, 1989). For example, people's memories of their college campus show that their mental maps are also semantically influenced. In priming studies, buildings prime each other more if they serve the same function (e.g., dorms, administration buildings, sports facilities, etc.).

Knowledge can also have spatial influences. As with memory psychophysics, some spatial remembering is a mixture of fine-grained and coarse-grained information. When given maps in the real world, there may be parts that don't quite line up. For example, on a city map, the streets may not be at 90-degree angles to one another, or the orientation of a town may not square with the standard compass points. Tversky (1981) has shown that, when these deviations are present, memories are distorted to smooth out the irregularities. For example, streets are remembered as intersecting at something more closely approximating 90 degrees. As an example of another lining-up distortion, many North Americans assume that South America is more directly south of North America than it is. It's actually more to the east. The western shore of South America is around the same longitude as the eastern shore of North America. People's memories reflect a combination of fine-grained information on the map and more coarse-grained, schematic knowledge about general orientations, causing people to make predictable errors.

The structure of mental maps influences more than just memory for space. It can also influence other types of thinking. Imagine people memorize a map, such as the map of the research center in Figure 11.11, and then read stories about events that occur in that area (Morrow, Greenspan, & Bower, 1987). While reading, people's use their mental maps influences comprehension. If a story character is described as thinking about an object in the building, the time it takes to read that sentence varies as a function of the distance between the character's current location and the object being thought about (Rinck & Bower, 1995). For example, if the story character is in the Repair Shop it will be easier for the reader to think of the pop machine (which is only one room away) than the clock, which is three rooms away. In general, the greater the distance, the longer it takes people to read. This is the **spatial gradient of availability**. The mental map captures spatial characteristics, and this spills over into comprehension.

Spatial Frameworks

We spend our time in various spaces and regions that are defined in particular ways—a kitchen, a mall, a highway, and so on. These spatial regions are called **spatial frameworks** and how we interact with them affects our memories for them.

When we learn about a location, especially a large one that we cannot see all at once, such as a mall or a town, we may derive our understanding from a map. We study the physical map to create our mental map. One consequence of this is that the orientation of the physical map has become ingrained into our mental map. So, when people need to estimate directions when facing a direction other than the original map orientation, they are slower to respond and may make mistakes (Evans & Pezdek, 1980; Levine et al., 1982; Waller, Montello, Richardson, & Hegarty, 2002).[2] It is as if the mental map were being viewed as a mental image. The greater the deviation from the orientation in which the map was learned, the more likely a direction error will be made. An example of this would be viewing a map of an unfamiliar mall that you are in and the orientation of the map does not match the orientation that you are facing when you look at it. If you do not do the requisite mental rotation, then you might head off in the wrong direction to try to get to a particular store.

For example, in Figure 11.12 people who have their mental maps aligned with the current orientation (A) are less likely to make errors than people who have their mental maps misaligned (B). This **orientation effect** is seen in the data in Figure 11.13. This extends to memory for observed spatial layouts (not just maps) that are either static or dynamic (like a soccer game) (Diwadkar & McNamara, 1997; Garsoffky, Schwan, & Hesse, 2002; Shelton & McNamara, 1997). It can also occur when a space is viewed from multiple **perspectives**. Each perspective can be stored as an orientation-specific viewpoint (McNamara, Rump, & Werner, 2003). However, it is not observed when people are active participants in the situation but only when they view it passively, such as when watching a film (Waller, Loomis, & Haun, 2004).

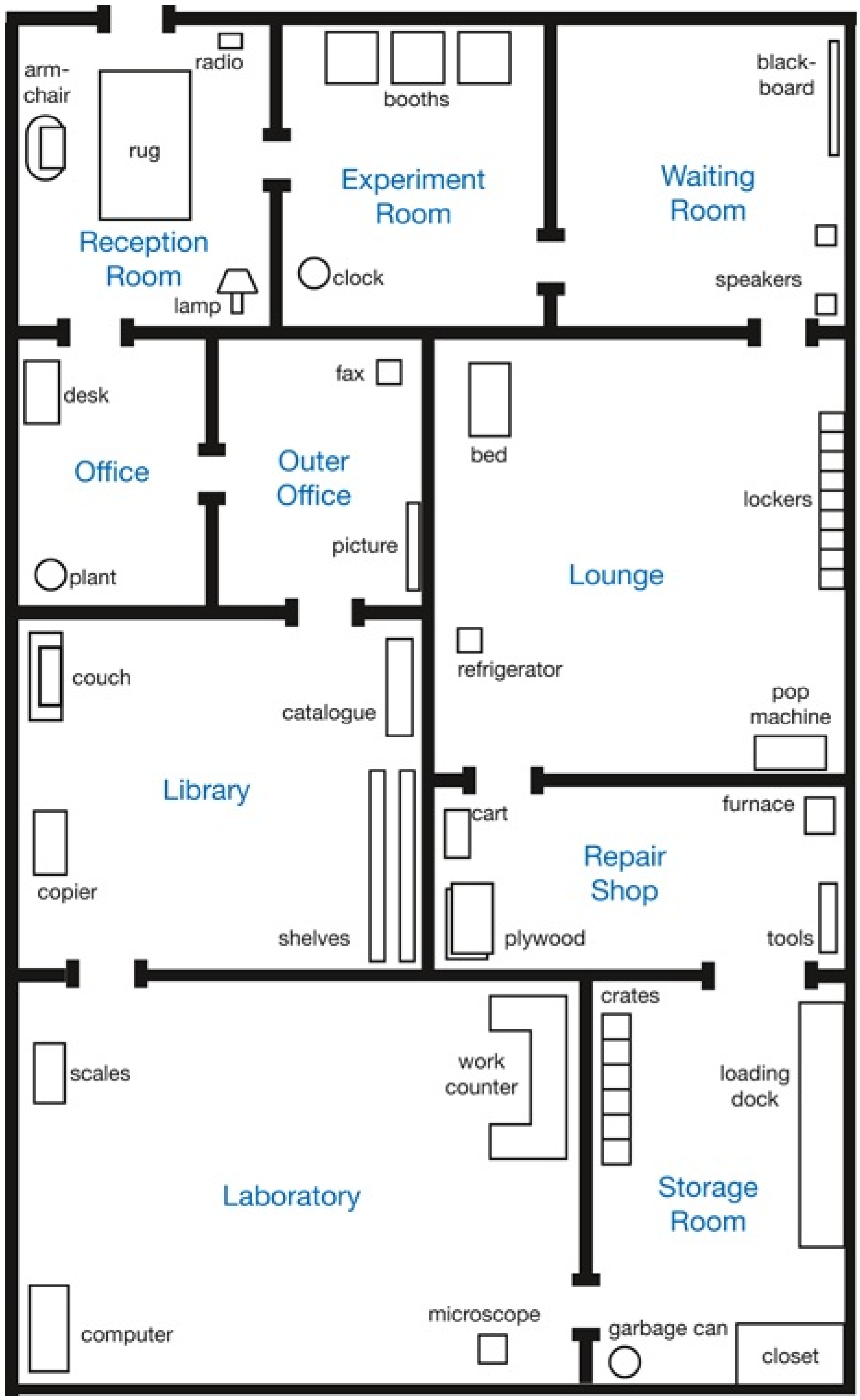

FIGURE 11.11 *Map of the Research Center*

Source: Rinck, M., Hähnel, A., & Becker, G. (2001). Using temporal information to construct, update, and retrieve situation models of narratives. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *27*, 67–80

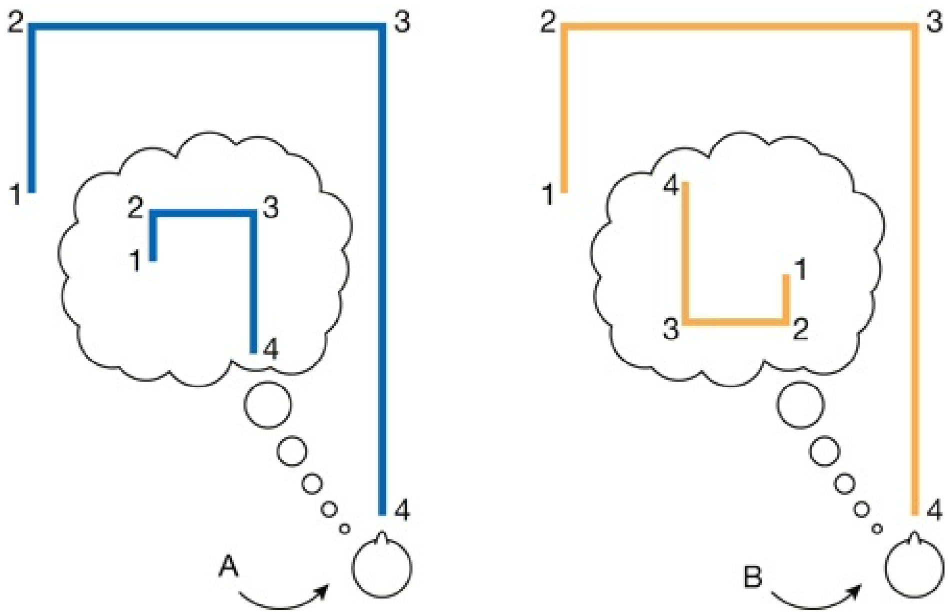

FIGURE 11.12 *Direction Judgment When the Memorized Map Is Aligned or Misaligned With the Current Orientation*

Source: Levine, M., Jankovic, I. N., & Palij, M. (1982). Principles of spatial problem solving. *Journal of Experimental Psychology: General*, *111*, 157–175

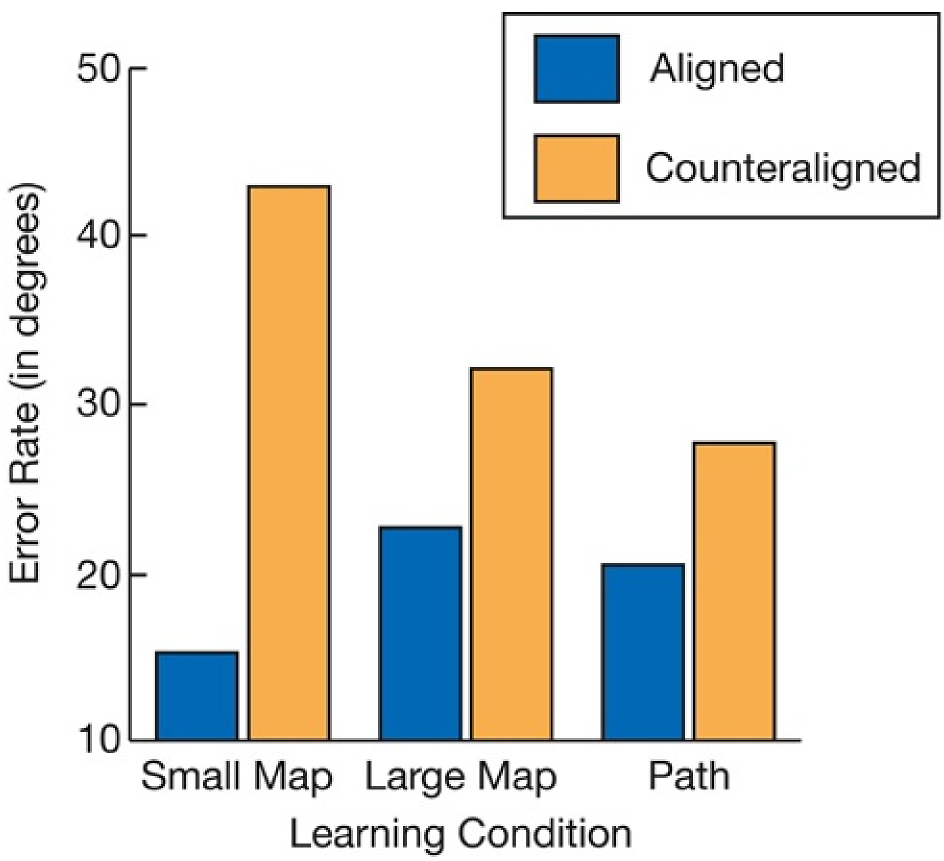

FIGURE 11.13 *Direction Judgment Errors a Memorized Space Is Aligned or Misaligned With the Current Orientation. This Data Reflects Spaces Memorized Using Small and Large Maps, as Well as by Travelling a Path in an Actual Space*

Derived from data reported in: Levine, M., Jankovic, I. N., & Palij, M. (1982). Principles of spatial problem solving. *Journal of Experimental Psychology: General*, *111*, 157–175

In general, not surprisingly, spatial memory is better when people actively experience a space (move around in it) rather than passively experience it (watch a video or read a map) (Chrastil & Warren, 2013). If people learn an area, such as a college campus, through experience rather than a map, there may be no single orientation influence (Evans & Pezdek, 1980). Natural exploration exposes a person to a wide variety of perspectives. Hence, the mental map does not have a preferred viewing orientation. Figure 11.14 shows data from a study in which students made direction judgments for their own campus or for the map of an unfamiliar campus. An orientation effect was only observed for the unfamiliar campus.

A person's perspective can have other influences. People often overestimate distances to locations near their current location and underestimate distances to places far away. This is illustrated in a study by Holyoak and Mah (1982). In this study, students at the University of Michigan estimated the relative east–west locations of cities in the United States. Importantly, they were asked to make these judgments by imagining they were standing on the West Coast looking eastward or from the East Coast looking westward, or were simply asked make estimates (keep in mind that they were in Ann Arbor, Michigan). The results, shown in Figure 11.15, reveal that location estimates were biased based on the perspective taken. People who imagined themselves on the Pacific Coast reported the western cities being farther apart and the eastern cities being closer together, whereas the opposite was true for those who imagined they were standing on the Atlantic Coast. Finally, people who were simply asked to estimate locations imposed a Midwesterner's bias by spreading out the distance among cities in the middle of the United States.

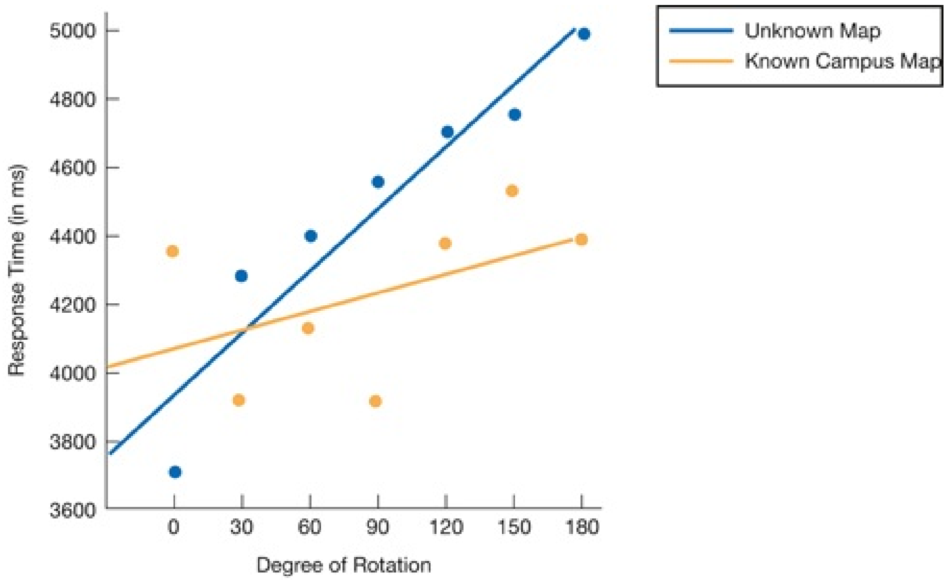

FIGURE 11.14 *Mental Rotation Effects for Unknown and Known Campus Layouts: Effects Only Observed for the Unknown (Map) Campus Condition*

Source: Evans, G. W., & Pezdek, K. (1980). Cognitive mapping: Knowledge of real-world distance and location information. *Journal of Experimental Psychology: Human Learning & Memory*, 6, 13–24

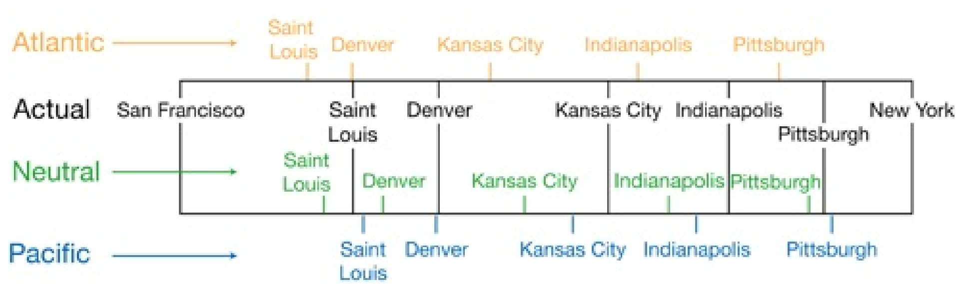

FIGURE 11.15 *Effects of Relative City Locating Depending on the Point of View Taken at Retrieval: (the Cities Tested Here Were San Francisco, Salt Lake City, Denver, Kansas City, Indianapolis, Pittsburgh, and New York)*

Adapted from: Holyoak, K. J., & Mah, W. A. (1982). Cognitive reference points in judgments of symbolic magnitude. *Cognitive Psychology*, *14*, 328–352

Mental maps are often created from experience with an environment or from reading a map. However, sometimes people create mental maps from language—for example, giving oral directions (e.g., “go east on Cleveland until you get to Swanson. Turn north. Then turn right at the third stop sign.”). Often people can navigate with only this type of information. How this information is given may not have a major effect on the mental maps in memory (Taylor & Tversky, 1992), although performance tends to be better when people learn from maps (Fields & Shelton, 2006).

Landmarks, Route, and Survey Perspectives

One of important need for spatial memory to support is navigation. How do we get from one place to the next? In this section we consider three types of information that can influence navigation. These are landmarks, route, and survey knowledge.

The first type of information that can influence spatial memory and navigation is **landmarks**, which are salient locations within an environment. These can include prominent buildings, bridges, statues, natural features such as lakes, and so on. Landmarks are important to spatial memory and mental maps because memories for space are distorted by these prominent features. Landmarks help define spatial regions and people distort their memory for nonlandmark locations toward the landmarks (Sadalla, Burroughs, & Staplin, 1980). For example, a prominent building on a college campus, such as a library, may serve as a landmark and define a region of campus (i.e., what buildings are near it). Conversely, other buildings, such as a dorm, would not be landmarks, and so do not define a region of campus. This influence is mediated by how landmarks are thought about (Bugmann, Coventry, & Newstead, 2007), such as whether people think about how important the landmarks are (larger influences) or how often they are visited (smaller influence). For instance, a tower on a college campus may serve as a notable landmark but hardly anyone ever actually goes up in it. Landmark influences are observed even when spatial memories are acquired verbally, as through a narrative (Ferguson & Hegarty, 1994).

The influence of landmarks on mental maps has been explained using the category adjustment theory (Newcombe et al., 1999), which we saw in the section on memory psychophysics. For this theory, people store information about the landmarks as categorical information as well as fine-grained information about the locations themselves. Memory then reflects a combination of these, which often results in nonlandmark locations being mentally drawn to the landmarks.

The second influence of mental maps is a **route perspective**, which the view people have when they navigate an environment. In a mental map, route information contains knowledge about which direction to turn (e.g., left or right), how long to travel along a given path, the presence of critical landmarks, and so on. It typically does not contain environmentally based cues, such as which direction is north, although it can if it is particularly salient (e.g., in the direction of the mountains). In general, route-based processing in spatial memory is supported more by areas in the parietal lobe and the caudate nucleus of the basal ganglia (Burgess, 2006, 2008).

When choosing a route from one place to the next, people can be influenced by a number of things and show certain biases in their selections. When people are traveling to a single destination, there is a bias to select routes that place smaller demands on memory, such as having a smaller number of turns (Bailenson, Shum, & Uttal, 2000), deviate less from a straight-line path (Hochmair & Karlsson, 2005), involve right turns (Scharine & McBeath, 2002), and get people to the border of the current region quickest (Hochmair, Büchner, & Hölscher, 2008). When choosing a route with multiple destinations, people show evidence of the hierarchical structure of the space, preferring routes that either start from outer to inner locations (MacGregor & Ormerod, 1996), that go from one regional cluster to the next (Graham, Joshi, & Pizlo, 2000), or that are more in the direction of a final destination (Fu, Bravo, & Roskos, 2015).

The alternative to a route perspective is a **survey perspective**, in which the spatial layout is presented as if it were being viewed from high overhead, such as from a helicopter. This is the perspective one has when viewing a map. Compared to route-based knowledge, survey-based knowledge processing is supported more by processing in the hippocampus (Burgess, 2006).

If people are asked to verify pictures of the area (walking perspectives or overhead views), memory is better for the perspective in which the information was originally learned (Shelton & McNamara, 2004). Overall, people who are better at remembering orientations, as with the spatial span task (see Chapter 5), do better with route learning, whereas people who are better at perspective tasks, such as mental rotation (also see Chapter 5), do better at survey learning (Fields & Shelton, 2006). This suggests that how information is represented in a mental map is influenced by how that information got into memory in the first place.

The different types of information that are available in a mental map not only contribute in different ways to spatial thinking and memory but also have different forgetting rates (Ishikawa, 2013). Specifically, survey knowledge (such as route choice, direction judgment, and configuration memory) appears to be retained well, whereas landmark and topological (e.g., what's uphill and downhill) knowledge is forgotten relatively quickly.

The idea that people are using different types of spatial information, such as metric information, spatial regions, landmarks, routes, survey perspectives, and so on, to process and remember information in their mental maps is supported by neurological evidence. The **parallel map theory** (Jacobs & Schenk, 2003) suggests two types of information are employed using two different sets of neurological structures. A **bearing map** is a representation of the current heading in an environment and corresponds to a coarse-grained representation of space based on the relative position to environmental locations. The bearing map involves the dentate gyrus and area CA3 of the hippocampus. This map tends to be more developed in males, who are better at dead reckoning navigation. This type of representation is also more sensitive to temporal order information.

The other type of representation is a **sketch map**, which is a representation of salient landmarks and corresponds to a fine-grained representation of space based on the known positions of landmarks. The sketch map involves area CA1 of the hippocampus. This map tends to be more developed in females and is more sensitive to spatial structure. The information from both the bearing and sketch maps is used to form an integrated map that includes both types of information, depending on what is available.

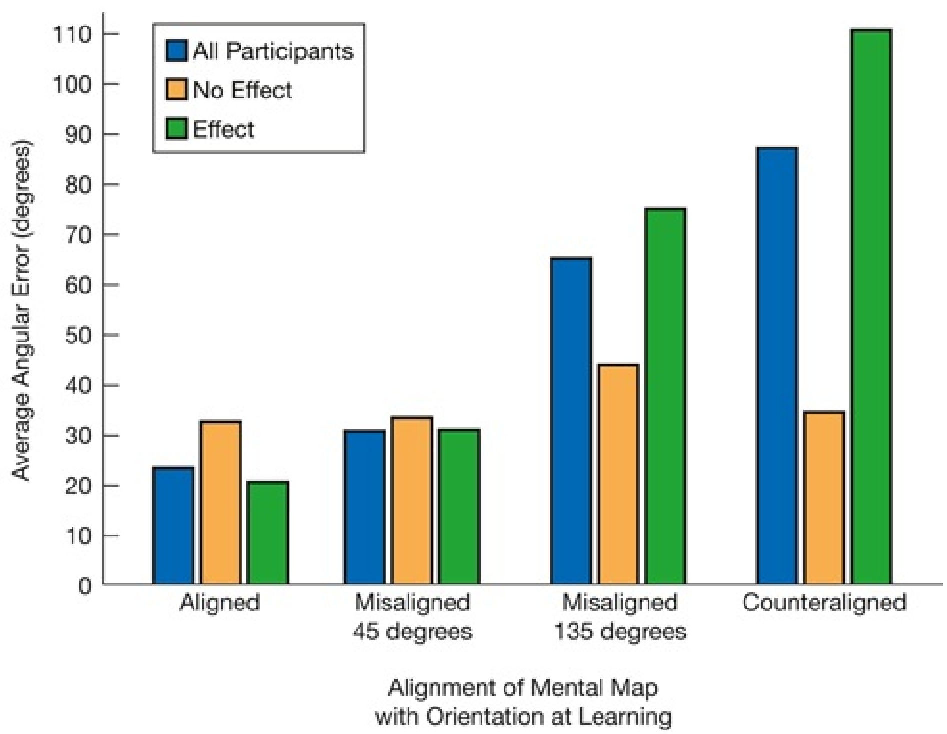

FIGURE 11.16 *Performance of Good and Poorly Misaligned Map Populations*

Adapted from: Rossano, M. J., Warren, D. H., & Kenan, A. (1995). Orientation specificity: How general is it? *American Journal of Psychology*, *108*, 359–380

PHOTO 11.1 *People vary in their spatial memory abilities to the point that different people can think that a specific location is in completely different directions*

Source: Purestock/Thinkstock

People vary in terms of the degree to which they can adjust to different map types and perspectives (Rossano, Warren, & Kenan, 1995). Figure 11.16 displays a division of people fall two categories. One type is relatively unaffected by how much their mental maps must be rotated, whereas the other type is susceptible to such errors (e.g., some people need to rotate a road map to their current driving orientation). Thus, there are individual differences in the ability to rotate a mental map. This may be related to how well people are able to use the spatial sketchpad in working memory. People who are better at mental rotation (see Chapter 5) are better at processing survey view information (such as that acquired from maps). This makes sense in that map use sometimes requires people to mentally rotate what was acquired from a physical map to match the current directional heading.

Stop and Review

People create memories of space called mental maps. These mental maps are not metric representations but are influenced and distorted by a wide range of factors. They are partially hierarchal due to the influence of map regions. They are also influenced by routes, landmarks, semantic relations, and how map information was originally learned. People’s use of mental maps is often influenced by and oriented around spatial frameworks, which may reflect the perspective taken during encoding or retrieval. These perspective effects can show a preferred orientation of the mental map, especially for areas that are less familiar. Neurophysiological evidence supports the idea that there are multiple types of knowledge that come together in the creation and use of mental maps.

MEMORY FOR TIME

The other major physical property we deal with here is time. In particular, how do people remember *when* things happened? Like space, memory for time is not perfectly related to the actual flow of time. Instead, there are systematic distortions that vary with respect to the type of temporal information people are trying to remember. There are three ways people can use memory for time (Friedman, 1993). The first is **temporal distance**, which is how long ago an event occurred. The second is **temporal location**, which is knowledge of when an event took place, such as knowing a date. Finally, there is **relative time**, which is knowledge of the relative order of two or more events, such as knowing which came first. Friedman uses the analogy of an archeologist to explain these three aspects of temporal memory. Temporal distance is like radiocarbon dating, used to determine the age of an artifact. Temporal location is like looking at the characteristics of an artifact to determine to what time it belongs, perhaps by comparing it to similar artifacts. Finally, relative time is used to place an artifact before or after others, perhaps based on the primitiveness or sophistication of one artifact relative to the others.

Phenomena

Using these three ways of thinking about time, we look at a number of phenomena that characterize memory for time and some of the theories that have been proposed to account for distortions in it. The first phenomenon is the **memory age effect**. People have difficulty placing events in time. It is not unusual to misremember events as having occurred even several years before or after when they actually happened. This distortion of temporal memories, like most memories, is more likely to occur with older memories. That is, the further back in time an event was, the more likely it is that a mistake will be made in remembering when it happened.

This forgetting of information in older memories is not that surprising.

However, as with other memories, there are **serial position curves** in the accuracy with which temporal information is retrieved (Toglia & Kimble, 1976). These serial position curves show a **primacy effect**. People have better memory for the time of the first event of a certain type. For example, it is usually easy to remember when you got your first speeding ticket but harder to remember when subsequent tickets were earned. There is also a **recency effect**, with people having superior memory for the time of recent events.

The ability to locate memories in time improves as memory for content gets better. An illustration of this **accuracy effect** is a study in which people heard either the melodies or titles of songs that were popular from two to 56 years before. Although people could locate songs in time better than chance when they did not consciously remember them (25% accuracy), temporal memory was better if either the melody or the title was recognized (38% accuracy) and was best if they could also remember the lyrics (60% accuracy) (Bartlett & Snelus, 1980). Essentially, the more information that was remembered, the more accurately people knew when the song was popular.

Another temporal memory phenomenon is the **scale effect**, which reflects the fact that memory for when an event occurred may be accurate at one scale of time but be distorted at another. For example, people may correctly remember that an event occurred on a Monday but misremember the week it occurred. The scale effect is described in detail in the Study in Depth box.

Memories for when events occurred can also be distorted by a process known as **forward telescoping**. This occurs when an event is placed more recently than when it actually occurred (Bradburn, Rips, & Shevell, 1987; Thompson, Skowronski, & Lee, 1988). For example, you might think something happened two years ago when it actually happened three years ago. A useful illustration of forward telescoping is from a study by Thompson, Skowronski and Lee (1988), in which students at Kansas State University kept track of events in their lives for three months. Afterward, they were asked to indicate when those events occurred. The results of this study are shown in Figure 11.18. As can be seen, older memories were judged as being more recent than they actually were. Forward telescoping is likely to begin two months after the original event, when sufficient forgetting has had an opportunity to take place. The primary cause of telescoping is the amount of time that has elapsed since the event.

A related phenomenon is **backward telescoping**. This is when recent events are placed further back in time than they actually occurred. Backward telescoping is largely confined to recent memories (Rubin & Baddeley, 1989). That is, very recent events can seem like they occurred longer ago than they actually did. For example, in the evening, it may seem that the morning’s events didn't even happen that day.

PHOTO 11.2 *We find it hard to locate events of our lives in time, unless there is some well-known date associated with the event, such as a holiday like Valentine's Day, even then, we might get the day right, but the year wrong)*

Source: IGraDesign/iStock/Thinkstock

STUDY IN DEPTH

In this section we describe a study by Thompson, Skowronski, and Betz (1993), which explored the scale effect in memory for time. This is an interesting study because it uses a diary method, which is uncommon in most scientific research on memory. In this study, 33 students from Kansas State University and 30 students from Ohio State University were recruited. The task for this study was for the students to first to record in diaries the events that they experienced during a semester at college. Each day they recorded one experience that they had. The students were told that the events had to be unique (so, buying a new sweater at the bookstore would count but buying a pop out of a machine would not), they could not be too embarrassing (after all, they had to turn their diaries in to the experimenters), and they had to have short, succinct descriptions. At the end of each week, the students handed in their weekly diary.

At the end of the term the researchers then tested students' memories for the events of that semester. What they did was read aloud the individual events from the student's own diaries. The student was asked to provide the date for when the event happened. To help the students with this task, they were provided a blank calendar (with no holidays or other such markers) of the months covered by the term.

What the researchers then did was plot the dates provided in terms of the deviations between the date that the student provided from memory and the actual date of the event. This data, and the scale effect that it reveals, is shown in Figure 11.17. Notice that there are peaks that occur at regular intervals (every seven days). Thus, as memory for the time of an event became distorted in terms of what week it occurred, there was some memory for the correct day. For example, a student might remember that an event occurred on a Thursday but be wrong about which week.

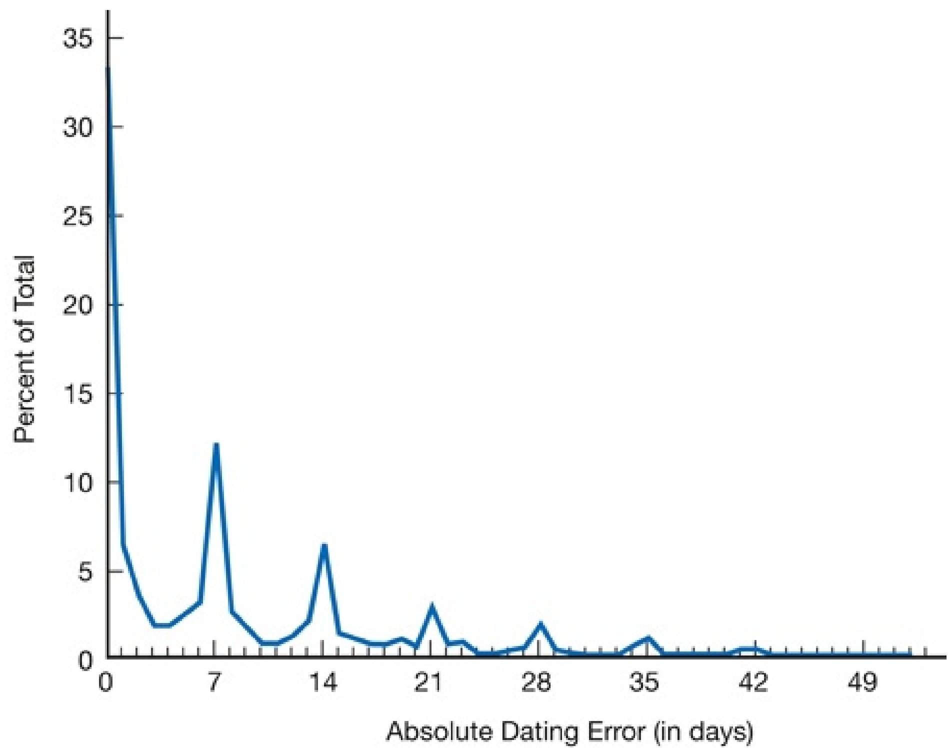

FIGURE 11.17 *Results Showing a Scale Effect in Temporal Estimation*

Source: Thompson, C. P., Skowronski, J. J., & Betz, A. L. (1993). The use of partial temporal information in dating personal events. *Memory & Cognition*, *21*(3), 352–360

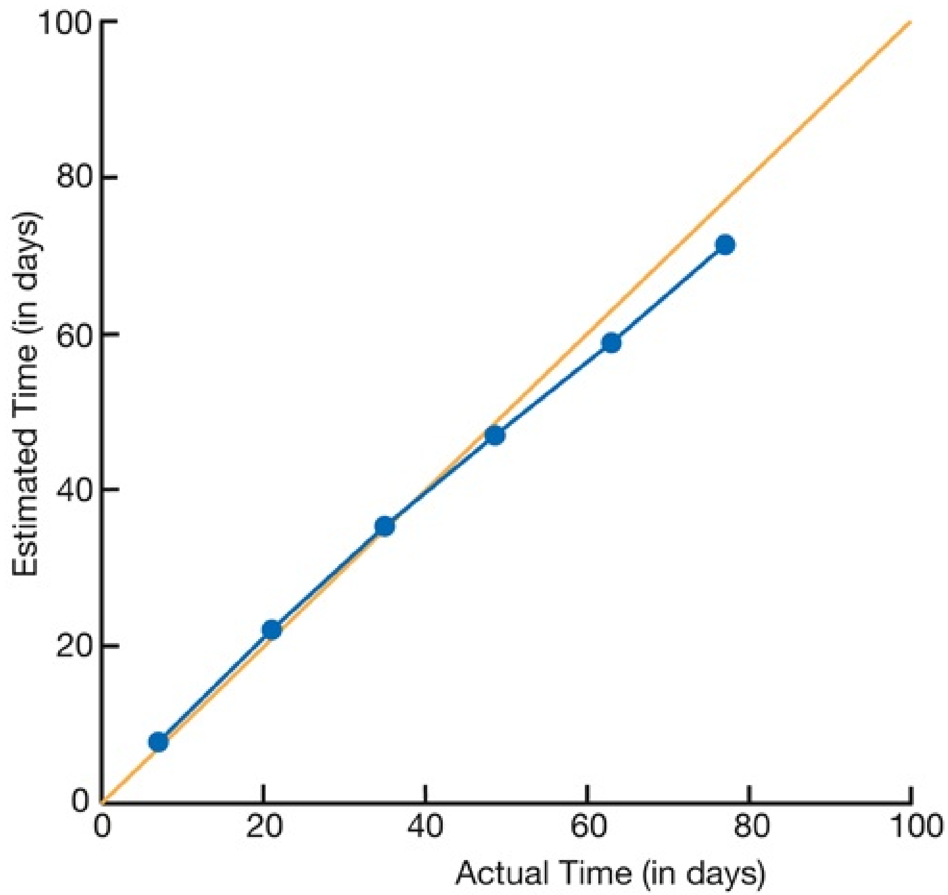

FIGURE 11.18 *Results Showing Forward Telescoping*

Derived from data published in: Thompson, C. P., Skowronski, J. J., & Lee, D. J. (1988). Telescoping in dating naturally occurring events. *Memory & Cognition*, *16*, 461–468

Telescoping effects reflect uncertainty in memory for time and may be a form of regression to the mean (Rubin & Baddeley, 1989). Forward and backward telescoping can be assessed using memory psychophysics—that is, by looking at which component of the memory processes is affected. Consistent with the presence of both types of telescoping, psychophysical functions using Stevens's Law show slopes that are less than 1 and y-intercepts that are greater than 0 (Ferguson & Martin, 1983). This means that there is a shift in memory for temporal events away from the extremes and more toward an average amount of time. Looking at memory for events, both in the news and in personal events, for events less than 100 days ago, memory is quite accurate. However, for events between 100 and 1,000 days ago there is backward telescoping, whereas for events older than 1,000 days there is forward telescoping, with older events showing more distortion (Janssen, Chessa, & Murre, 2006).

Finally, memory is good for the **order information** of a sequence of events, that is, which event came first, second, and so on. As a consequence, people can locate events in time by considering event order, either a forward or backward order. Anderson and Conway (1993) found that people better recalled a sequence of events in their lives if they are recalled in a forward order, although a backward order of recall was fairly efficient as well. Recall attempts based on the relative importance of details of an event were the most difficult. Whitten and Leonard (1981) found that students recall their precollege teachers best when they try to remember them in a backward order, worse in a forward order, and worst of all when they tried to remember them in a random order. Thus, in some way, temporal information is encoded as a part of memory.

Processing Factors

A number of accounts of temporal memory have been suggested. Following Friedman (1993), here are some of the more prominent ones. These explanations can be broadly classified as being based on distance-based, location-based, and relative time factors.

Distance-based factors produce time estimates based on how far in the past an original event is from the present, perhaps using the strength of the memory trace (Brown et al., 1985). The longer it has been since a trace was accessed, the weaker it will be. In contrast, stronger traces refer to more recent events. Thus, the strength of a memory can be used to determine its age. This can explain the memory age, recency, and relative ordering effects, as well as why events that have been thought about frequently are remembered as being closer to the present. These memories gain strength each time they are retrieved (Brown et al., 1985).

Also, people can use context (Glenberg et al., 1980) because context is constantly in flux. Two events close in time are likely to be associated with similar contexts but events that are distant in time have more distinct contexts associated with them. These contexts can be either external or internal. For this view, the greater the difference between the current context and the one associated with the memory, the older that trace is assumed to be. Your present situation is generally more similar to what it was last week than a year ago or even 10 years ago.

It should be noted that, overall, distance-based factors have difficulty with the primacy and accuracy effects, and forward or backward telescoping. There is little evaluation of the nature of the content of the memory, only its age.

Location-based factors involve locating a memory in time based on the content of the memory trace. The simplest way this could happen is if people store a tag with the memory for the event. That time tag would convey the hour, day, month, year, or whatever was relevant. All people would need to do is read off this information. For example, I know that I officially started my current job on August 23, 1993. This is directly stored in my memory. Although some people have suggested that time tags may be associated with a biological clock (Tzeng, 1976), most memories do not have this sort of detailed information.

Another way is for people to locate a memory in time based on inferences using knowledge in the trace. People figure out the time of an event using information they know, as well as similar events whose time is known. For example, I remember an event that happened on May 1, 1983. I remember seeing some people in old convertibles driving through Cleveland’s near west side, shouting and waving signs. This was in the late afternoon and I was on my way home from school. I know it was May 1 because these people were members of the local Communist party and there was also a brief segment about them on the news that night. They were shouting about how there should be a revolt of the workers and that communism should replace the current political system (it didn’t happen). I know it was May 1 because this is an important date in communism, and I know it was 1983 because I was coming home from high school, which would have made it 1980, 1981, 1982, or 1983. I also remember discussing this with a girl I was dating at the time, and I did not date her until my senior year, so it must have been 1983. Thus, using my knowledge of the event along with the circumstances of my life at the time, I can infer the date.

Location-based factors account for the memory age effect due to a loss of either a time tag or context information. As for serial position curves, primacy effects are attributed to both a superior memory for the event itself and any temporal information associated with it. This is assisted by the fact that the early occurrence of events of a type makes those events more temporally distinct and thus makes them better remembered. Scale effects are accounted for by the loss of a time tag, an error at one level of contextual control but not another, or being able to use information in the memory to reconstruct only part of the time accurately. For example, remembering an event that occurred at church could be easily reconstructed to be one that occurred on a Sunday, which is very likely to be accurate, but the memory is vague enough that the year cannot be reconstructed. Telescoping effects are explained as reconstructive processes by assuming that memory traces are distorted based on the amount of content recovered. Relative ordering effects can be accounted for by time tags and reconstruction processes, although not as well. Finally, accuracy effects are easily accounted for in that the more that is retained in a memory, the more accurate the time tag or the more reliable the information used for reconstruction.

For **relative time factors**, temporal order information is stored directly in memory. Information about other events and their temporal relation to one another is stored along with the memory of the event itself. This could happen by an associative chaining of memories (Lewandowsky & Murdock, 1989), along with an event are stored associations of prior occurrences of events of the same type. To locate an event in time, one assesses how it is associated with other related events. Did it occur before or after these other events? Thus, by determining where the event is in a sequence, one can figure out its temporal location.

Another way to encode and recover when events happen is that every time an event occurs all of the related events are activated in memory (Hintzman, Summers, & Block, 1975). People are reminded of previous similar situations. These reminded events then get associated with the memory for the current event. So, the more recently an event has occurred, the more events that are associated with it. Of course, the first event of that type has no additional associated memories. Thus, people can locate events in time, at least relatively, by using information about other events that were associated with it during the reminding process. This would explain why it is easier to correctly order events that are similar than those that are different.

These views directly account for relative order effects. The storage of order information is what these views are all about. Moreover, they can explain other things, such as the memory age effect in that older memories are more likely to have lost the needed associations. They can also explain serial position effects. Older memories have fewer associations, so they are easier to locate in an order. Conversely, a recency effect occurs because newer memories have had the least amount of forgetting and a large number of associations. Forward telescoping is explained as a loss of associations, making the memory seem not so old.

While people may use relative time information, it does not appear to be a major factor. In a study by Friedman (2007), people were given pairs of events, such as movies or class announcements, and were asked to judge whether the temporal order of the two was correct. Moreover, these events were either related or not (such as having the same major actor). If they were related, then people should make relative time associations. However, the results revealed no such process, suggesting that people do not necessarily draw these temporal associations as they experience events.

Categorical Adjustment Theory

Using an approach similar to understanding spatial memory, Huttenlocher, Hedges, and Bradburn (1990) developed a version of the **categorical adjustment theory** for temporal memory. Again, this model assumes that memories are stored at two levels: a fine-grained and a coarse-grained level. The coarse-grained level would include large categories of time, such as 7, 10, 14, 21, 30, and 60 days. Estimates of when events occurred reflect a combination of both the detailed and categorical information. The temporal categories serve both to place limits on which events could have occurred (such as knowing that a lecture must have happened sometime between the beginning and the end of a semester) and as a basis for rounding estimates when there is uncertainty at a fine-grained level.

This fuzzy trace approach accounts for memory age and accuracy effects because the forgetting at the fine-grained level is more likely to occur as memories get older. Serial position effects are also explained. Recency effects are due to a relatively small amount of forgetting, and primacy effects reflect memories that are more likely to occur at a temporal border and so can be easily located within that category. The use of coarse-grained information explains scale effects because the scales often correspond to categorical values. Finally, both forward and backward telescoping are explained as tendencies to use categorical prototypes when fine-grained information is forgotten.

There are other factors that can influence how people locate memories in time. For example, how the information is reported, such as whether it is an absolute or relative time format (Janssen et al., 2006). People prefer absolute time formats (exact dates) for more recent events and relative time formats for more remote events, consistent with the idea that more recent events are likely to have more details. Moreover, people prefer absolute time formats for personal events compared to news events, which is consistent with the idea that personal events are more likely to be well encoded and have sufficient details available for absolute dating.

Stop and Review

Memory for time is worse than memory for space. In addition to memory errors due to age and serial position, temporal memory shows scale and telescoping effects. Despite these errors, people are able to remember the sequence or order in which events occurred, even if they cannot place them properly in time. Various factors have been suggested as influencing temporal memory. These include distance factors based on the age of the memory, location-based processes based on knowing when the information occurred in time, and relative time-based factors that derive estimates of time based on memory for the order of events. These multiple processes are reflected in mixture models, such as the category adjustment theory, that take into account a number of mental processes acting on memory for time.

PUTTING IT ALL TOGETHER

This chapter looked at memory for space and time. Your memory for spatial information is fairly good. When distortions occur, they are systematic to the point of obeying psychophysical laws. This often involves a mixture of more detailed metric information along with more general, gist-like information about spatial regions, as captured by the category adjustment model. The mental maps in memory are rarely metric representations but are hierarchically distorted by spatial regions and the temporal order in which you learned information. In addition, mental maps can be influenced by routes and semantic knowledge. They are also distorted by the spatial frameworks derived from the particular spatial perspective you take, although these influences decline with experience. Also important is the presence of landmarks. Finally, neurological evidence suggests that you can use either a bearing map or a sketch map and that people vary in the effectiveness with which they use these different kinds of maps.

Memory for time is less reliable than memory for space. You can make a number of judgments about temporal memory, including judgments of temporal distance (how long ago did an event happen?), judgments of temporal location (when did the event happen?), and relative time (which event happened before the other?). Memory for when events occurred is influenced by how old the memories are, as well as being influenced by a serial position curve. Temporal memory also exhibits a scale effect. You may be accurate at one level of detail but incorrect at another. Temporal memory can also be distorted forward or backward in time, as with forward and backward telescoping effects. Finally, you are fairly good at remembering the order in which events occurred, provided that the events are similar in some way. A number of factors can influence memory for when events occurred. Distance-based factors include knowledge of the age of the memory itself, as well as changes in context. Location-based factors involve information in memory itself, including the explicit encoding of temporal information, as well as inferences drawn using memory contents. Finally, relative position factors involve knowing the sequence of events to help determine when a given event may have happened. Overall, like spatial memories, temporal memories are likely a mixture of a combination of factors, and this can be captured by theories such as the category adjustment theory.

STUDY QUESTIONS

1. How can psychophysical principles be applied to memory?
2. To what degree and how are memories for space distorted with respect to actually perceiving a space? Why?
3. What is the category adjustment model and how does it apply to memory for space?
4. What are some of the major factors about a space that can influence the organization of a mental map?
5. What are the different ways of experiencing or learning the information that will go into a mental map and how do they influence the final nature of that mental map?
6. How good is a person's memory for time?
7. What are some of the characteristics of memory that affect the ability to remember when something happened?
8. In what ways does memory for time get distorted?
9. What are the major processing factors that account for people's ability to remember when things happened?
10. How does the category adjustment model account for the variations in people's ability to locate memories in time?

KEY TERMS

- accuracy effect
- backward telescoping
- bearing map
- category adjustment theory
- distance-based factors
- forward telescoping
- hierarchical view
- hybrid theories
- landmarks
- location-based factors

- memory age effect
- metric view
- order information
- orientation effect
- parallel map theory
- partially hierarchical view
- perspective
- primacy effect
- psychophysics
- recency effect
- relative time
- relative time factors
- route
- route perspective
- scale effect
- semantic relationships
- serial position curves
- sketch map
- spatial frameworks
- spatial gradient of availability
- spatial theories
- Stevens's Law
- survey perspective
- temporal distance
- temporal location
- temporal theories

EXPLORE MORE

Here are some additional readings to for you to further explore issues having to do with memory for space and time.

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NOTES

1 See Maddox, Rapp, Brion, and Taylor (2008) for a related account involving social relations.
2 See Avraamides, Galati, Pazzaglia, Meneghetti, and Denis (2013) for an extension of this to narrative memory.

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CHAPTER 12

Autobiographical Memory

Many of the issues presented in other chapters covered aspects of human memory, such as knowing how to ride a bike, remembering whether a word has been seen before, or knowing what a bird is. While these are important, there are other memories that involve what most of us would consider more central to who we are as individuals. These are the memories that make us unique. They help form our identities and give structure to our lives. Knowledge of a person's memory is a very intimate thing. When we meet new people, an important part of getting to know one another is an exchange of memories, often by providing excerpts from our life story. The type of memory that forms our life story is **autobiographical memory** and it is the focus of this chapter. Autobiographical memory covers events, situations, and other knowledge about yourself that spans your entire life.

This chapter covers general characteristics of autobiographical memories, some special methods for studying autobiographical memories, and the various levels of detail in them. We consider how autobiographical memory has a narrative character. It can provide us with different perspectives, which depends on general world knowledge, and can vary across cultures. An important part of autobiographical memory is superior memory for more emotional periods of our lives, the occurrence of involuntary memories, and how this relates to the condition of PTSD. We look at superior memory for surprising events that can give rise to what are known as flashbulb memories. Finally, we look at the reminiscence bump for central portions of our lives.

CHARACTERISTICS OF AUTOBIOGRAPHICAL MEMORIES

In this section we examine what autobiographical memories are. This includes their relationship to episodic and semantic memories, their nature, and the ease with which they are retrieved.

Episodic or Semantic?

Because autobiographical memories are about a person's own life, are they a kind of episodic memory? In a way, yes. However, they are much more than that. Autobiographical memories go beyond the information found in episodic memory alone. They are far more constructive and integrative, often spanning multiple events. In contrast, episodic memories are each confined to a single event.

In addition to episode-specific memories, autobiographical memory also contains generic information about yourself. This can include things such as your address, phone number, job, and so on. Much of your life story involves relatively stable, semantic-like information. This is reflected in the fact that information about semantic concepts (e.g., names of animals) shows similar search and access processes as semantic autobiographical information (e.g., names of friends) (Unsworth, Brewer, Spillers, 2014). Still, autobiographical memories differ from semantic memories, per se, in that they are uniquely about ourselves. Moreover, not only does autobiographical memory have semantic aspects, but semantic memory is influenced by autobiographical memory. For example, semantic knowledge of famous people is more accessible if they are autobiographically significant, such as a personal hero, even when accounting for frequency and recency of exposure (Westmacott & Moscovitch, 2003).

Varieties of Information

Autobiographical memories are about events in our lives and how they are interrelated. This may involve integrating events separated by long periods of time. They are amalgams of all kinds of information about our everyday experiences, including knowledge of sensory experiences (what things looked, sounded, smelled like, etc.), where things happened, how people acted, what people said, and what emotions were felt (Rubin, 2006). Moreover, autobiographical memories contain interpretive inferences about how one event relates to others and what it means to us.

During retrieval, people typically report general information followed by specific details (Anderson & Conway, 1997). For example, a person may report something like this:

I remember when I was in high school back in Cleveland Ohio. I had this Latin teacher. He used to constantly terrorize our class. It was horrible. I remember one day he gave a really hard exam. To make sure we didn't cheat, he put a chair up on his desk at the front of the class. He then sat on the chair, staring at us all, making us more nervous and tense than we already were.

It is less common for people to report information in the reverse order, starting with the details and working out to general information. This suggests that autobiographical memories are organized around general themes. Within these more generalized chunks are the details of our lives.

TRY IT OUT

Autobiographical memory has a strong temporal order bias. People prefer remembering events from the beginning to end, rather than the reverse, or even remembering details based on importance. This can be illustrated by asking people to recall 10 details from a set of 12 events.

What you will need are a set of 12 life events that most people will have already had. Here is a list that you can use, although you can think of your own if you wish: "going to a birthday party," "getting an important message," "visiting relatives," "going on a shopping trip," "playing a game," "getting a job," "moving to a new home," "learning to drive," "coming home from school," "taking a trip," "meeting a new friend," and "attending a sporting event."

For this study, you need at least 12 participants, although more would be better. Read the life event titles to these people, one at a time. Have your participants write 10 details down on a sheet of paper, for each of the 12 events. Next, have the participants recall the details of four of these events in a forward order (from the beginning to the end), four in a backward order (from the end to the beginning), and four in an importance order, starting with the most important detail and then proceeding to the least important. You should also time how long people take to do each list using a stopwatch. If you can, randomly mix up which events get assigned to which condition for each person, as well as the order of the conditions.

When you are done, average the times for each person for each of the conditions and then average the times across your participants within each of the conditions. What you should find is that people recall more details and/or be fastest when the information was recalled in a forward order compared to a backward order or based on importance, thereby illustrating the sequential nature of autobiographical memories.

This organizational structure suggests that autobiographical memories are complex. They contain information at a variety of levels of detail and span broad periods of time. This complexity influences retrieval time. It takes longer to retrieve an autobiographical memory than a typical episodic or semantic memory. Semantic and episodic information can be retrieved in one or two seconds. However, autobiographical memory retrievals may take two to 15 seconds (Anderson & Conway, 1997). This slower processing time reflects a need to access more information and to sort through the autobiographical structure to locate specific memories.

There appear to be gender difference in autobiographical memory. There is a tendency for women to report more episodic elements than men, to have more detailed and evaluative event reports, and to have more repetitions in their reports (Fuentes & Desrocher, 2013; Wang, 2013). In comparison, men tend to retain and place more factual information (Schulkind, Schoppel, Scheiderer, 2012). That said, whatever information is encoded into autobiographical memory is forgotten at similar rates for men and woman (Wang, 2013).

Methods of Autobiographical Memory Study

Autobiographical memory differs from other types of memory because it is uniquely personal and the events were encountered long before people step into the laboratory. While all of the standard methods of assessing memory can be adapted to study autobiographical memory, there are some techniques that are typically not found in the study of other kinds of memory. One of these is the **Galton–Crovitz cue word method**. This was originally developed by Francis Galton (1822–1911) and brought back into modern use by Crovitz and Schiffman (1974). This method involves presenting people with a series of words (such as “tree”) and asking them to report the first memory that comes to mind. This technique is useful in assessing the distribution of memories across the lifetime. This is particularly relevant when we discuss the reminiscence bump later in the chapter.

A serious problem with autobiographical memory studies is that, unlike many other assessments of memory, the researchers often do not know what people actually experienced over the course of many years. A way to get around this by using **diary studies**, in which research participants keep diaries or records of daily events for a long period of time. This allows the experimenter to assess if a memory is accurate. Because diary studies are very long and labor intensive, they are not common. Some diary studies involve only a single person keeping track of events in his or her life over a multiple year period (Linton, 1975; Wagenaar, 1986; White, 2002). Other diary studies have several people record information for many weeks or months and then test them later. For example, the assessment of the scale effect in temporal memory described in Chapter 11 involves this kind of diary method.

Improving Your Memory

How can you improve your ability to retrieve your autobiographical memories? Well, one way would be to keep a diary or journal of your life events. The act of recording daily events improves later memory for them (Szollosi, Kereztes, Conway, & Racsmány, 2015). The recording process itself serves to help you rehearse the event, making it more memorable later. Moreover, when thinking about your daily events, this also causes you to draw inferences about how different things may be related to each other within the same day or to other events from your own life, thereby weaving your daily events better into your life narrative and improving memory for them.

Functions of Autobiographical Memory

What role does autobiographical memory play in memory and cognition? Harris, Rasmussen, and Berntsen (2014) identified four functions of autobiographical memory. First, it has a **reflective function**, in which autobiographical memory is positive self-focused attention aimed at understanding or defining who one is. This provides goals and directions to one's life. An example of this is thinking that you should become a physician because you want to help people and you also want to make a good living. Second, autobiographical memory has a **social function**, in which it is more positive and other-focused to serve interpersonal and conversational functions. An example of this would be thinking about your life in order to share it in a conversation with someone you've just starting dating and you want to get to know you.

Third, autobiographical memory has a **ruminative function**, in which memory is self-focused attention directed at perceived losses and threats. Examples of this would be thinking about people you know who have died or relationships that have been lost. This appears to be the least used function of autobiographical memory. Finally, autobiographical memory has a **generative function**, which is aimed at having a positive impact on the world and creating a legacy. This helps a person draw on prior experiences to teach others, develop a sense of achievement, and develop a sense of contact with people from the past. Overall, the uses of these functions decline as one grows older with the exception of generativity, which appears to increase.

Stop and Review

Autobiographical memory is a complex form of memory with components of episodic and semantic memories. They contain information about both individual events and stable characteristics of a person. Autobiographical memories are woven out of basic knowledge about the events in our lives along with the inferences and interpretations of those events. These memories are complex and constructive, requiring more time to bring them to mind. Our autobiographical memories play a number of roles to give structure to our understanding of our lives. These functions include reflecting on past events, interacting socially with others, ruminating on our past losses, and thinking generatively about the qualities of our lives and how we will be of benefit to those in the future.

LEVELS OF AUTOBIOGRAPHICAL MEMORY

Autobiographical memory is hard to simply and easily describe because it is made up of different types of information. One way to parse this type of knowledge is by the length of time covered (Conway, 1996). Using this approach, there are three levels that can be identified: (1) the *event level*, which refers to individual events; (2) *general events*, which refer to extended sequences or repeated series of events, often sharing a common component; and (3) *lifetime periods*, which are broad, theme-based portions of a person's life.

An example of these different levels is shown in Figure 12.1 (Conway, 1996; Conway & Pleydell-Pearce, 2000). At the top are two lifetime periods, which happen to overlap. These are the education and work themes. Within each of these are a number of components that make up that theme. Each of these components is associated with a collection of general events. For example, in the work theme, "working as a bartender" is associated with a number of general events, such as “first day on the job,” “working nights,” and “inventory.” Each general event is also associated with memories of specific episodes at the lowest level of the hierarchy. Note this division of autobiographical memories also seems to apply to episodic future thinking (D’Argembeau & Demblon, 2012).

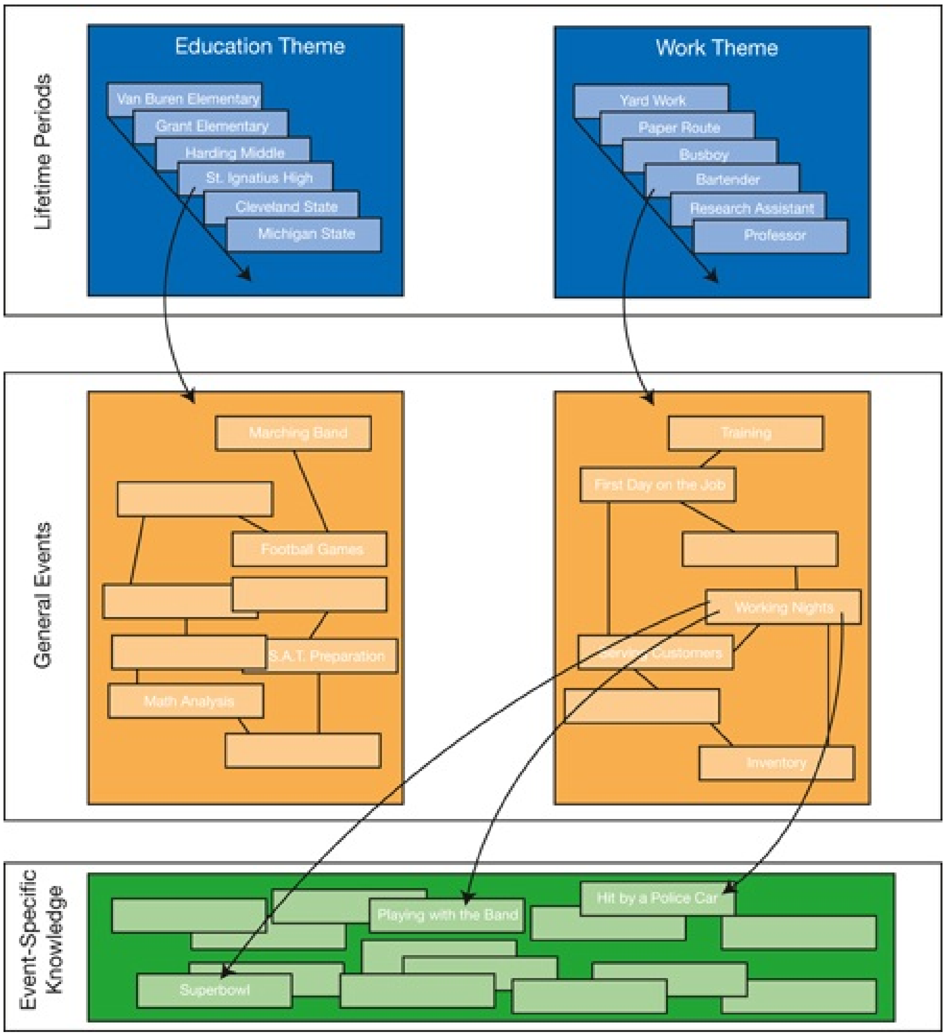

FIGURE 12.1 *Hierarchy of Autobiographical Memories*

Adapted from: Conway, M. A. (1996). Autobiographical memory. In E. L. Bjork & R. A. Bjork (Eds.), *Memory*. San Diego, CA: Academic Press

Event-Specific Memories

Event-specific memories most closely correspond to episodic memories. These are memories for specific periods of time that involve a common activity occurring at a particular place. For example, the Latin teacher sitting on his chair while perched on his desk is an event memory. Event memories contain perceptual and contextual details about what things looked or sounded like, as well as details about time and space. Finally, event memories can contain internal context information, such as emotional reactions, or physiological states.

Rubin and Umanath (2015) detailed event memory characteristics in a way that essentially identified them as the event models of event cognition (Radvansky, 2012; Radvansky & Zacks, 2011, 2014), which are similar to the mental models (Johnson-Laird, 1983; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998) discussed else-where in the book. Event models are mental simulations of events in a real or possible world that are grounded in a spatial-temporal framework. They also included entities that can be objects or people, including one's self. Associated with these entities are their proprieties, such as how they look, their internal states, their goals, and so on. These events models convey structural information such as spatial position, social/kinship relations, ownership, and so on. Finally, there can be linking relations that join multiple event models into a coherent sequence of events, as with temporal or causal links between events (Radvansky & Zacks, 1997). Event models are flexible in that people can take a variety of perspectives on events, such as the view from one's own perspective, another person's, or yet some other third-person view. For example, think about an event in which you had a conversation or some other interaction with another person. You can imagine it from the perspective you had at the time, from the perspective of the person, or from some other, imaginary third person, in which both of you would be in view.

While most event-specific memories are lost over time, others endure and become important as singular memories. This is the opposite of many memory processes, which tend to move toward making information more semantic and schematic (Pillemer, 2001). For an event-specific memory to be retained as a single event, it needs to have some special quality. Pillemer outlined four ways this can happen. First, they can be memories of initial events that have many goal-relevant memories that follow them—for example, a memory of a childhood experience of going to the hospital for an injury sets a person on the path toward becoming a doctor. Second, they can be memories of turning points when a person's life plan is redirected—for example, being confined to a wheelchair as a result of a car accident. Third, they can be memories of anchoring events that serve as a basis for a major belief system in life—for example, having a religious experience. Finally, they can be memories of anomalous events that are used to guide future behavior—for example, remembering an embarrassing incident at work when a person got caught goofing off when the temptation arises to do that again. These qualities of event-specific memories can make them easy to remember and hard to forget.

General Event Memories

At an intermediate level of autobiographical memory are **general events**. One type of general event is a sequence of events that forms a larger episode. For example, the first day on the job is a general event composed of the various specific events of that day, such as getting a tour of the building, being assigned a desk, receiving literature on company policies and benefits, and so on. The extension of an event across time and space as people unify several smaller events (Burt, Kemp, & Conway, 2003). This may involve linking events to one or more themes.

The other type of general event is a repeating event. For example, your memory for a class taken last year is a general event. The different class sessions are not a sequence of events because they were separated by large periods of time. Still, the repeated event quality of the class can be used to organize experiences into a general event of being in that class. For both types of general events, there is often a personal goal that is affected by the extended event.

The creation and storage of general event memories requires integrative and interpretive thinking. Integration is needed because different events must be brought together into a common memory trace. This is particularly clear for recurring situations, such as taking a class. Interpretation is also needed because people must understand how the subevents go together. For example, in a general event memory of the class, memory for receiving a grade on an exam must be related in some coherent way to the memory for taking the exam and its relation to studying before that.

Lifetime Period Memories

At the highest level of the hierarchy are **lifetime periods**. These are long periods of life that are organized along a common theme, such as “early childhood,” “education,” or “career.” Lifetime periods give people a sense of structure about the progression and development of life in the service of goals or preferences. When people recall autobiographical memories, if they go beyond a single general event they are likely to confine retrieval to a given theme (Barsalou, 1988). For example, when recalling information about previous work experiences people are unlikely to recall information about various relationships they were involved in, unless those relationships overlapped with their work experiences (such as dating a coworker).

Evidence for the Hierarchy

This autobiographical memory hierarchy is more of a heuristic than a hard and fast categorization. There are many cases where it is unclear at what level a given memory belongs. For example, is a memory of meeting one's roommate for the first time a single event or a general event memory of a sequence of events that happened in quick succession? Also, information may be divided up into subcomponents at the different levels. A general event may be broken down into other general events A memory for taking a class may be broken down into different parts of the semester. Thus, there is a recursive quality to autobiographical memories in which smaller and smaller parts can be nested into a larger description (Barsalou, 1988). An example of this recursive decomposition is shown in Figure 12.2.

It should also be noted that people typically have different aspects of their lives going on concurrently. Various extended life events overlap. Thus, there are a number of ways that autobiographical memories relate to one another (Barsalou, 1988). For example, Figure 12.3 shows events from different lifespan periods overlapping in time. After all, life does not start and stop depending on our goals and preferences.

Despite the fuzzy nature of this division of autobiographical memory, there is evidence to support this hierarchy, to some degree. For example, lifetime period reports are more likely to be elicited when people are cued to recall an autobiographical memory in response to a cue word (e.g., tell me a memory of your life based on the word "lock") or a social instruction (e.g., imagine you are describing the event to a friend). In comparison, event-specific reports are more likely to be elicited when people are cued when there is no specific target audience or following hearing a narrative centered on a lifetime theme (e.g., a description of someone running for high school class president) (Schulkind, Rahhal, Klein, & Lacher, 2012). Thus, there is some flexibility in how people draw information out of autobiographical memory. Also, over time, the lower one goes in the hierarchy, the more likely information can be forgotten, with more abstract relations in autobiographical memory being retained longer (Mace, Clevinger, & Bernas, 2013).

Moreover, this hierarchy has some neurological support. People with dense amnesia can recall lifetime period and general event information but not specific episodes. One patient, S. S., became amnesic after a case of herpes simplex encephalitis when he was about 40 years old (Cermak & O'Connor, 1983; McCarthy & Warrington, 1992). The virus damaged part of his left hemisphere.

Although he was of high intelligence (I.Q. of 133), he had severe memory problems. S. S. could not remember specific events from his life but could recount general aspects of his life experiences, such as his job. So, although he had trouble remembering at the event level, he could remember at the general and lifetime period levels.

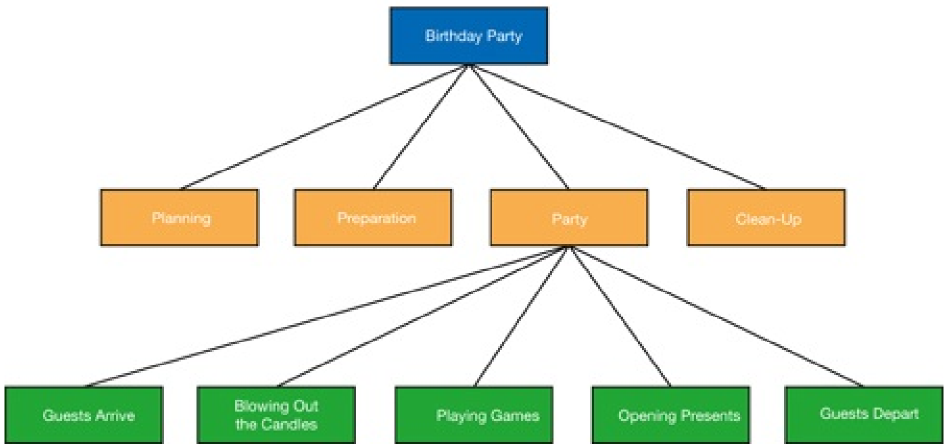

FIGURE 12.2 *The Recursive Process of Breaking Down an Autobiographical Memory into Smaller and Smaller Parts—in This Case, a Memory of a Trip*

Adapted from: Barsalou, L. W. (1988). The contents and organization of autobiographical memories. In U. Neisser & E. Winograd (Eds.), *Remembering Reconsidered: Ecological and Traditional Approaches to the Study of Memory*. New York: Cambridge University Press

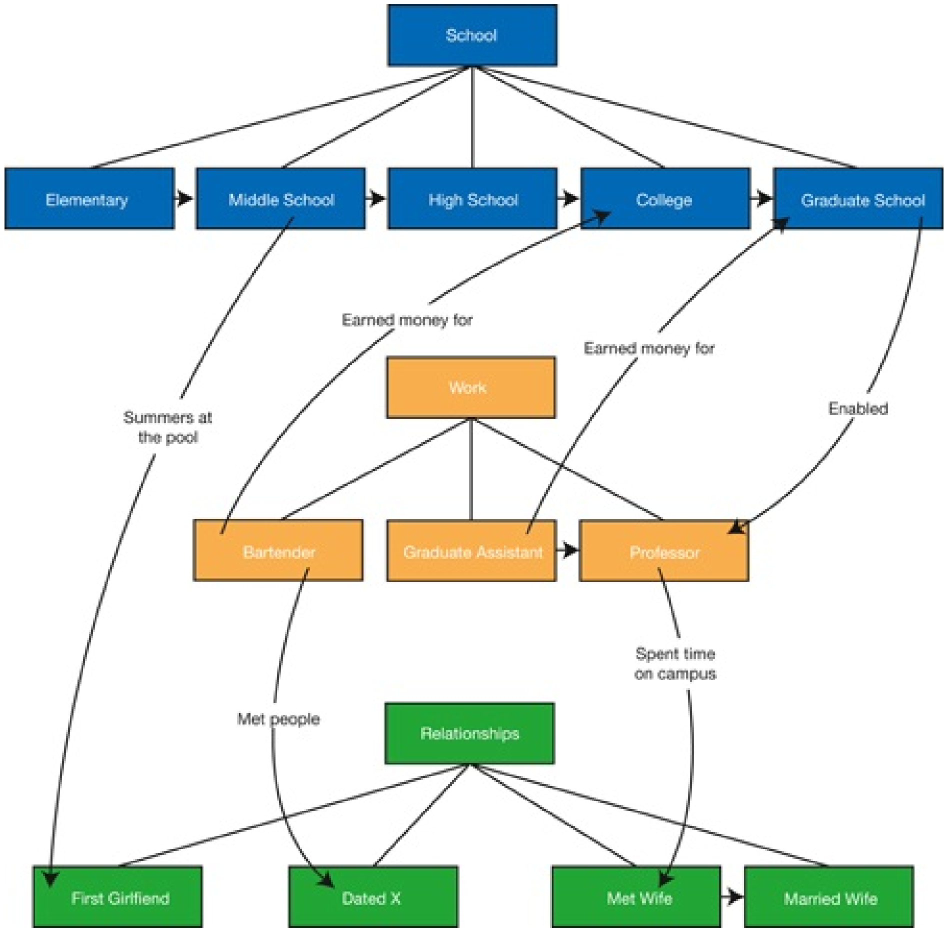

FIGURE 12.3 *Temporal Overlapping of Various Lifetime Periods with Different Themes Based on Common, Shared Specific and General Events*

Adapted from: Barsalou, L. W. (1988). The contents and organization of autobiographical memories. In U. Neisser & E. Winograd (Eds.) *Remembering Reconsidered: Ecological and Traditional Approaches to the Study of Memory*. New York: Cambridge University Press

A similar case is K. C., who suffered damage to the frontal-parietal region of his left hemisphere and the parietal-occipital region (BAs 7 and 39) of his right hemisphere as the result of a motorcycle accident at the age of 30 (Tulving, Schacter, McLachlan, & Moscovitch, 1988). He could not remember any life events. For example, he could not remember the circumstances of his brother's tragic drowning death 10 years before. However, he did remember semantic knowledge including knowledge of his job, which he had recently begun, and even personally relevant information, such as the floor plan of his childhood home (although he couldn't say which room was his), the names of his school classmates, and places where he had vacationed. This distinction between what is and what is not remembered supports the idea that autobiographical memory for events is a separate from memory of general knowledge.

In contrast, K. S., who had a right anterior temporal lobectomy to control her epileptic seizures, could recall specific life events but not general knowledge about the people involved (Ellis, Young, & Critchley, 1989). She also had trouble with the names of famous people and product brands (e.g., Margaret Thatcher or Coca-Cola). Thus, in a sense, she had the ability to store memories at the event-specific level but not more general information.

Another person with autobiographical memory trouble was P. S., a man in his late 60s with bilateral damage to his thalamus. This condition led to profound anterograde amnesia as well as extensive retrograde amnesia for autobiographical memories, but not more semantic, nonpersonal information (Hodges & McCarthy, 1993; McCarthy & Hodges, 1995). For instance, although he was married, he could not recall any details of his wedding. He also knew that he had three sons but could not provide any details about their births. He also did not recognize photos of family events. However, he could recognize famous faces accurately and could place them in chronological order for when they were famous, but could not remember public events (e.g., the Watergate scandal). Thus, P. S. lost the ability to remember autobiographical events, as well as the people involved in them.

Stop and Review

Autobiographical memory can be divided into three levels. At the event-specific level are memories of individual events, which is closest to episodic memory. At the general event level are memories for extended and repeated events. Finally, at the lifetime period level are memories that span broad, thematically related parts of our lives. This hierarchy is supported by studies of the effectiveness with which people retrieve memories, as well as neurological evidence from brain-damaged patients who have selective deficits.

AUTOBIOGRAPHICAL MEMORY AS LIFE NARRATIVE

Autobiographical memories are **life narrative** memories (McAdams, 2001). This follows a general human tendency to organize our experiences into some sort of narrative structure (Bruner, 1991), rather than simply a structure it based on semantic information (Conway & Berkerian, 1987). People often access information in autobiographical memory using event components that are found in narratives, such as people, places, activities, and other thematic information

(Barsalou, 1988; Burt, 1992; Conway 1990; Lancaster & Barsalou, 1997; Wagenaar, 1986). In general, autobiographical memories can be elicited by any event feature that is stored with the event, sometimes involuntarily (Berntsen, 1996).

PHOTO 12.1 *Autobiographical memory is like a life narrative—it is the story of ourselves that we tell ourselves and others, and it can be improved if one keeps a diary of the events experienced from day to day*

Source: Liquorice/DigitalVision/Thinkstock

While autobiographical memories can be triggered by a wide range of cues, such as how things look and sound (Willander, Sikström, & Karlsson, 2015), olfactory cues (the smell of things) have gained special attention. There is some suggestion that odors are particularly effective at helping people remember events (Chu & Downes, 2002). They are more likely to elicit memories that people rarely think about (Rubin, Groth & Goldsmith, 1984) and elicit feelings of nostalgia (Reid, Green, Wildschut, & Sedikides, 2015). Also, odors are more likely to elicit memories from the first decade of life than words or pictures are (Willander & Larsson, 2006). The autobiographical memories elicited by odors tend to be more emotional (Herz, 2004; Herz & Schooler, 2002). This may be because the olfactory nerves are more directly connected to the amygdala, which is important for emotion processing. In essence, because smells are more connected to emotional experience they are more likely to be remembered.

When people are probed for autobiographical memories, they tend to retrieve them in clusters of other events that occurred at a similar time (Brown & Schopflocher, 1998b), as is expected if they are part of a story. Moreover, people are most often reminded of events that are causally related (either as a cause or as an effect) and are reminded of events that share the same person, place, or activity (Brown & Schopflocher, 1998a), similar to how people organize their memories of actual stories (Zwaan & Radvansky, 1998).

To give autobiographical memories a narrative style, people may draw on semantic memory. As is discussed in Chapter 9, people have scripts of common events. These are used to structure autobiographical memories, giving them a temporal order. Moreover, people better recall life events in a forward order.

Moreover, people are faster at recognizing important details of the event (Anderson & Conway, 1993). For example, if you remember a trip to a restaurant, you are more likely to replay it back in your mind in a forward order, as it was experienced. However, if you were just thinking about one or two important details, such as a marriage proposal, you would to be able to retrieve it quickly without the need to start at the beginning.

While narrative structure is important, it is not always observed. In a study by Burt, Watt, Mitchell, and Conway (1998), people took photos during the course of their daily lives. Later, they were shown the pictures with the task of putting them in the correct temporal order. Performance was terrible. People were correct only 9% of the time, although they did better if less than a week had passed, in which case they were correct 35% of the time. This low performance most likely occurred because the snapshots were just random bits that did not create well-defined narratives and so were more difficult to correctly structure and order.

Perspectives in Autobiographical Memory

Narrative structure also shows itself in our autobiographical memory experiences. When you think about events from your life, there may be an accompanying mental visual image. These images can vary in their perspective. Sometimes we experience a memory from our original point of view. These are called **field memories** because they capture the original field of view. In contrast, at other times, we view an event from outside of ourselves and may even see ourselves in it. These are called **observer memories** (Nigro & Neisser, 1983). The very fact that we have observer memories emphasizes the constructive nature of autobiographical memory. Note that these perspective differences not only apply to autobiographical memories of the past but can also apply to episodic future thinking for upcoming experiences. There is a greater bias for episodic future thoughts to be more from an observer than a field perspective, perhaps because the events have not yet occurred (McDermott, Wooldridge, Rice, Berg, Szpunar, 2016).

There are three factors that influence how a memory is experienced (see Table12.1). One is the age of the memory. In general, older memories are more likely to be observer memories. A second is emotionality. Generally, the more emotional the memory, the more likely it is experienced as a field memory (Siedlecki, 2015). For example, one would be more likely to remember an emotionally intense event, such as getting a marriage proposal, from the perspective that it was experienced.Finally, there is one's self-awareness in a situation. Generally, the more self-aware people are, the more likely they are trying to understand their role in the larger event and so this tends to lead to more observer memories. For example, an observer memory is more likely to be generated when people remember giving a speech.

TABLE 12.1 *Dimensions and Criteria for Field and Observer Memories*

Dimension	Field Memory	Observer Memory
Age of memory	Newer	Older
Emotionality	More emotional	Less emotional
Self-awareness	Less self-aware	More self-aware

Schema-Copy-Plus-Tag Model

People use schemas and scripts to help reconstruct incomplete autobiographical memories. The older autobiographical memories are, the more schema-consistent the reports are likely to be (Eldridge, Barnard, & Bekerian, 1994). Thus, schemas guide the formation of our memories and how and what we remember. However, if you think about your life it does not feel like you have a memory full of generic, stereotypical events. Instead, you tend to better remember the parts that are unusual. Memory is heavily schematic, but what is schema-inconsistent is more memorable.

So, what is the solution to this apparent paradox? One idea is that our memories represent both schematic and unique aspects of an event. This is the **schema-copy-plus-tag model** (Graesser, Gordon, & Sawyer, 1979; Graesser & Nakamura, 1982; Graesser, Woll, Kowalski, & Smith, 1980). When you experience a new event, you first activate the appropriate schema. That schema, or at least the relevant parts of it, is then the basis for your event memory. This schema helps reduce the need to actively think about and process every little detail. You can simply assume that most details are about the same as they usually are.

In addition, you associate “tags” with a memory to denote the important details that were inconsistent with the schema, thereby making memory of that event unique. For example, if you go to a restaurant and the manager tells you that you do not have to pay, this is going to be represented by a tag in memory. Because autobiographical information is focused on the self, people are more likely to show a greater benefit for tagged information when the event memory involves themselves or another familiar person (Colcombe & Wyer, 2002).

This use of schemas and tags is in line with the distinction between item-specific and relational processing (see Chapter 7). Schemas provide relational processing, whereas the tags are item-specific processing. Storing memory for event information as a schema and tags can further be influenced by how the information was learned. Learning that emphasizes the structure of the event, such as sorting things based on themes, facilitates the schematic aspect, whereas learning that emphasizes item-specific information, such as filling in missing letters in words, facilitates the tag aspect (Hunt, Ausley, & Schultz, 1986).

Representing autobiographical knowledge this way has two consequences. First, because trivial details are less likely to be directly represented in a memory, it is difficult for people to distinguish between schema-consistent parts that were actually present and those that were not. Second, because the tag is part of the memory trace, it is easy for people to remember what was odd about an event. This has some unfortunate consequences for education. Students’ memories for what happened during class is often better for unusual things that happened during lectures, such as spilling coffee or jokes that were told, rather than the content of the lectures (Kintsch & Bates, 1977).

Cultural Differences

The autobiographical memories that we form are likely to depend on the kinds of narratives and stories we are familiar with. Thus, given that narrative and story forms can vary across cultures, it is expected that there would also be differences in autobiographical memories as well (see a special issue of the journal Memory on this topic: Alea & Wang, 2015). For example, indigenous Australians produce autobiographical memory reports that have more context and detail than non-indigenous Australians (Nile & Van Bergen, 2015). Also, compared to Americans, Japanese men and women tend to be focused less on the individual and more on the collective (including self-continuity, social-bonding, and behavior-directing aspects of memories of personal events) (Maki, Kawasaki, Demiray, & Janssen, 2015). That said, some aspects of autobiographical memory are stable across cultures. For example, across cultures, people feel that positive events are more likely to play central role to defining who they are more important part of their life stories (Zaragoza Scherman, Salgado, Shao, & Berntsen, 2015).

Stop and Review

Autobiographical memory is a life narrative, paralleling the structure of actual stories. This constructive aspect is seen in the distinction between field and observer perspectives in which people can experience an autobiographical memory from multiple perspectives. Although autobiographical memory construction and retrieval can be guided by schemas in semantic memory, people use tags to help remember the odd, unusual, unexpected, and important aspects of an event. Thus, we have better memory for the unusual details of events rather than the anticipated, common aspects. Finally, because of its narrative structure, people from different cultures with different narrative styles organize and structure their autobiographical memories differently.

EMOTION AND AUTOBIOGRAPHICAL MEMORY

A central aspect of experience is the emotions we feel during events, as well as our emotional reactions when we remember. Like most memories, autobiographical memory has a forgetting curve. People remember more recent autobiographical events better than older ones (Whitten & Leonard, 1981). However, emotion adds some complexity. First, the more emotional an event, the more likely it is going to be remembered (Nadel & Jacobs, 1998). Moreover, consistent with the **Pollyanna principle**, also called the **positivity bias**, over time there is a tendency to remember pleasant events better than unpleasant ones (Wagenaar, 1986), which are forgotten more rapidly (Holmes, 1970; Meltzer, 1930). Moreover, the emotional intensity of negative events is more tempered than positive events (Walker, Skowronski, & Thompson, 2003).

Although there is a bias to remember more positive life events, there are circumstances when we remember negative events, such as those involving anger, shame, and depression. These negative autobiographical memories differ from positive ones. People tend to focus more on central details and less on peripheral details of negative memories (Berntsen, 2002), leading to better detailed memory for things in the focus of attention (Kensinger, 2007). This is likely brought on by increased activity in the amygdala during negative events.

The increased focus on central details in an emotional autobiographical memory, at the expense of memory for peripheral details, is called **tunnel memory** (Safer, Christianson, Autry, & Österlund, 1998). For example, if you saw an automobile accident, you are likely to better remember aspects about the accident (what colors the cars were) and more poorly remember surrounding details, such as how many other people were in the area. This is because your attention had tunneled in on the central aspects of the emotional event. Tunnel memories can also alter other memory phenomena. For example, tunnel memories are less likely to exhibit boundary extension (see Chapter 5). Tunnel memories are more common for negative events, perhaps because these central details are more critical in a negative event (e.g., an automobile accident). Positive events are less likely to hinge on a single critical detail (e.g., falling in love). Despite these differences between positive and negative memories, it should be noted that, overall, memory is driven more by the intensity of the emotion than by whether it is positive or negative (Talarico, LaBar, & Rubin, 2004).

Involuntary Memories

While the retrieval of autobiographical memories may require some time and effort, there are occasions when they are consciously retrieved spontaneously and involuntarily (Berntsen, 1996, 2001, 2009).[1] An example of an **involuntary memory** might be while you are walking to class in the rain and step into a puddle. This spontaneously brings to mind the time you were walking home from school in kindergarten and saw a puddle on the sidewalk with the sky reflected in it. It looked like the puddle had depth and was a window into another world. Involuntary memories occur regularly (Berntsen & Rubin, 2008), at least two to five times a day. They can be thought of as a basic mode of memory use (Berntsen, 2010; Ebbinghaus, 1885/1964) and are likely associated with processing of the default mode network.

STUDY IN DEPTH

An illustration of the positivity bias in autobiographical memory is a study by Breslin and Safer (2011). This study assessed memories of the major league baseball World Series for 2003 (which was won by the New York Yankees) and 2004 (which was won by the Boston Red Sox). In 2008 they tested 1,563 major league baseball fans. These people were either fans of the Yankees or the Red Sox and lived in Boston, Massachusetts, Cincinnati, Ohio, New York, or Washington, DC. Of these people, 277 had actually attended a game in 2008 in one of these cities. Also, 1,286 of them regularly read online Yankees or Red Sox reports during the time that they were questioned. These people were contacted via websites and given a souvenir pen in return for answering a few baseball-related questions.

Prior to answering questions about the 2003 and 2004 games, people were reminded of who had won each of those two years. During testing, people were asked to recall and recognize specific details of those two series. These included questions such as the score of the final game of each series, the winning and losing pitchers' names, the location of the game, and whether the games required extra innings. People were also asked to assess their own memories.

The results are shown in Figure 12.4. As can be seen, people had better memory for events that happened during the World Series when their favorite team won (which resulted in higher levels of positive emotion). That is, there was a positivity bias for people to better remember events for which they had more positive memories.

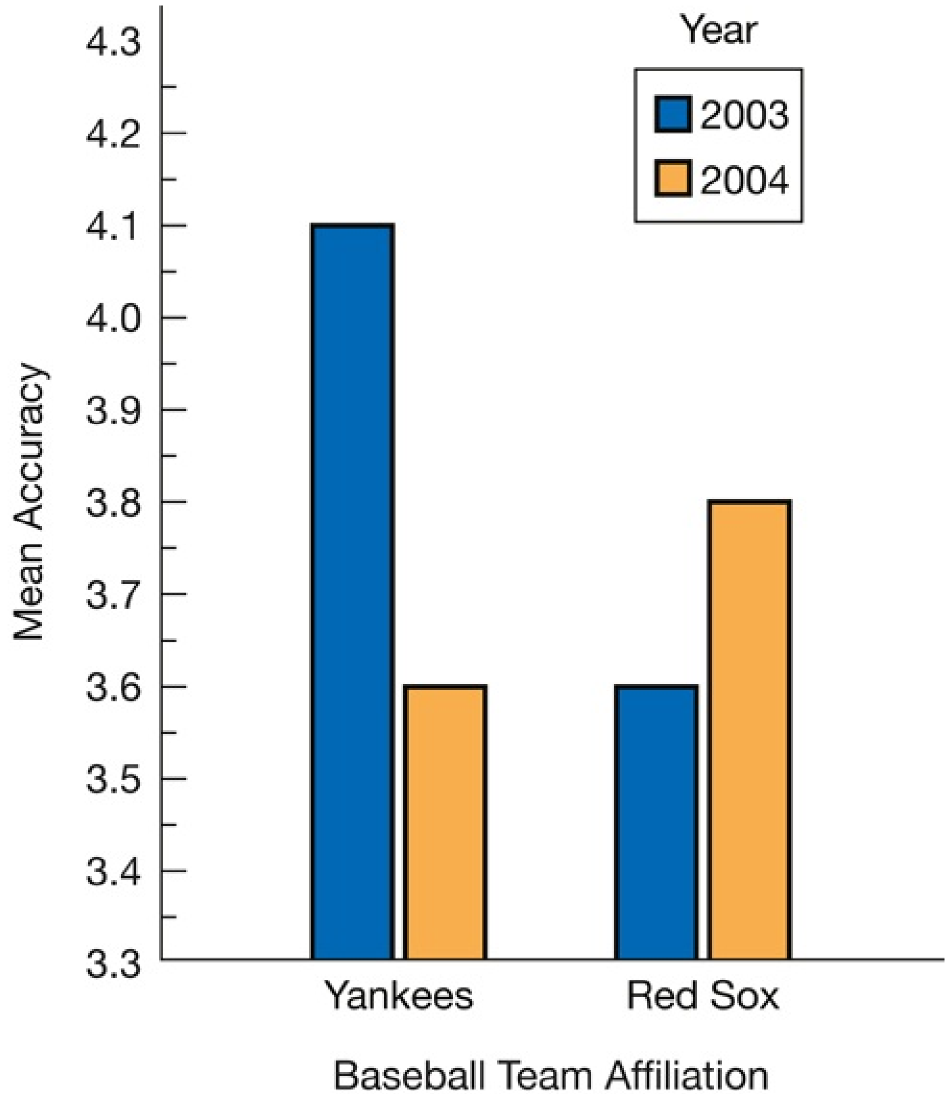

FIGURE 12.4 *Memory for Information About World Series Games for New York Yankees and Boston Red Sox Fans Illustrating the Positivity Bias*

Adapted from: Breslin, C. W., & Safer, M. A. (2011). Effects of event valence on long-term memory for two baseball championship games. *Psychological Science*, *22*(11), 1408–1412

Involuntary memories are more likely to be triggered by more unique aspects of experience that serve as diagnostic memory cues (Berntsen, Staugaard, & Sørensen, 2013). Involuntary memories tend to be more emotional than voluntary memories and be more often about positive than negative events (Berntsen, 1996, 2001). Finally, involuntary memories are more likely to be triggered by verbal, non-visual cues (Mazzoni, Vannucci, & Batool, 2014).

Spontaneous memories not only occur for past events, but also for episodic future thinking. Such spontaneous future-oriented thoughts tend to be more positive than spontaneous memories of the past (Berntsen & Jacobsen, 2008). These spontaneously generated future thoughts also tend to be less event-specific and be more on the level of general events (e.g., I should take an advanced chemistry next semester) or lifetime periods (e.g., I wonder what kind of job I will get after graduation) (Anderson & Dewhurst, 2009).

Negative spontaneous memories are a symptom of post-traumatic stress disorder (PTSD), in which people have involuntary flashbacks to a negative, aversive event. These flashbacks can be quite persistent (Berntsen, 2001) and may be one of the driving forces behind PTSD (Rubin, Berntsen, & Bohni, 2008; Rubin, Boals, & Berntsen, 2008). With PTSD, traumatic memories are often quite realistic (Alexander et al., 2005), even after a long period of time (Porter & Peace, 2007). In addition, with PTSD, there is a bias for prior memory and future thoughts to be less specific and more general (Brown et al., 2014).

For traumatic involuntary memories, as with PTSD, steps can be taken to lessen their severity using what is known about autobiographical memory. When people with PTSD have flashbacks, they feel more stress and anxiety when they recall them from a field view than from an observer view (McIsaac & Eich, 2004). Taking the point of view one had during an event is more likely to reinstate the emotional and physiological states experienced at the time. However, taking an outsider's perspective helps detach people and reduces anxiety. That said, observer memories may also contribute to the perseveration of PTSD symptoms over the long term (Kenny et al., 2009). Also, although there can be directed forgetting (see Chapter 8) of autobiographical memories (Joslyn & Oakes, 2005), the salient negative involuntary memories of traumatic events, such as those associated with PTSD, are responded to very emotionally (Berntsen & Hall, 2004) and attempts to use directed forgetting may have the opposite effect of making them more prominent (Dalgleish, Hauer, & Kuyken, 2008). Finally, there is also some evidence that efforts to alter PTSD-inducing memories by leveraging some aspect of the reconsolidation process is not effective (Wood et al., 2015).

Stop and Review

Autobiographical memory is affected by emotion, in terms of both mood-dependent memory and a positivity bias to remember positive events longer than negative events, which is consistent with the Pollyanna principle. When people do remember negative events, there is a tendency to have tunnel memories that focus on the more central event details. Finally, memories can come to mind unbidden, as with involuntary memories. Although most of these are emotionally positive, in some cases they are negative. Such involuntary negative memories can take a pathological bent when they are associated with PTSD.

FLASHBULB MEMORIES

So far, our discussion of autobiographical memory has focused on relatively mundane aspects of life. However, we also have memories for surprising and important events that are very vivid, have a great deal of detail, and are resistant to forgetting. Highly detailed memories for surprising events are called **flashbulb memories** (Brown & Kulik, 1977) because it is as if the mind had taken a picture of the surprising events as they were occurring.

As examples of flashbulb memories, many people who were around at the time remember where they were and how they heard about the assassination of President Kennedy. A generation later, people can tell you detailed information about hearing about the explosion of the space shuttle *Challenger*. People are also likely to have flashbulb memories for the news of Princess Diana's death (Hornstein, Brown, & Mulligan, 2003) or the terrorist attacks on September 11, 2001 (Schmidt, 2004; Tekcan, Ece, Gülgöz, & Er, 2003). That said, such memories are better if they were personally experienced rather than simply heard about (Pillemer, 2009). Note that, while most of the research on flashbulb memories tends to focus on negative events (which make the news broadcasts), flashbulb memories can also exist for positive events (such as finding out that one is going to have a baby). These tend to be much more personal and have a greater impact on one's lives (Demiray & Freund, 2015; Kraha & Boals, 2014).

A striking feature of flashbulb memories is that they contain detailed information for not only the event itself but also for the context in which it was learned. It is not unusual for people to remember who told them about an event, what the weather conditions were, whom they were with, where they were, what they were wearing, and so on. This contextual information is not directly relevant to what was learned. Still, it seems to be stored at a high level of detail.

Flashbulb Memories Are Special

The original explanation for flashbulb memories was that there is a special memory process, called the "Now Print!" mechanism, somewhere in the neural coding of long-term memory (Brown & Kulik, 1977). This mechanism is triggered when something of great importance occurs. By storing so many details, it allows people to later sort out and identify the important components. This is especially critical for rare events. Thus, this would have some survival value. For example, there is evidence that people are more likely to remember their locations and from whom people heard the news when they encounter surprising events (McKay & Ahmetzanov, 2005), although, interestingly, memory for the emotions experienced at the time are not well remembered (Hirst et al., 2009). These points noted, other work on flashbulb memories has failed to support this strong position that flashbulb memories are accurate and unchanging. This is discussed in the next section.

PHOTO 12.2 *When surprising and emotional events happen, we may form flashbulb memories that are highly detailed and longer lasting than our typical event memories; flashbulb memories are so named because it is as if the brain took a picture of what was happening at the time, although this idea later turned out to be somewhat flawed*

Source: jgroup/iStock/Thinkstock

Flashbulb Memories Are Not so Special

It has been suggested that flashbulb memories are just normal memories for important events. They are normal because they can contain errors, be distorted, and be forgotten over time (Christianson, 1989; McCloskey, Wible, & Cohen, 1988; Schmolck, Buffalo, & Squire, 2000; Talarico & Rubin, 2003). They can also include misinformation from hearing other people's stories of the event

(Niedźwieńska, 2003). Flashbulb memories involve people creating autobiographical memory stories for themselves. These accounts then remain relatively stable over long periods of time (Kvavilashvili, Mirani, Schlagman, Foley, & Kornbrot, 2009), although flashbulb memory events experienced as a child may fade over time (Weems et al., 2014).

With flashbulb memories, there is some forgetting, people's accounts change, and incorrect information can creep in. For example, a person might remember that she was having lunch with a friend that she typically has lunch with when she heard the news of an event. However, in truth, the person she remembers having lunch with was somewhere else that day. Thus, flashbulb memories can contain inaccurate information that may be based on schematic reconstructions of what typically happens. Flashbulb memories also may reflect a belief in the accuracy of the memories that emerges from the emotional reaction to the event, rather than the actual accuracy of the memory. The stronger the emotional reaction, the more a memory is believed (Talarico & Rubin, 2003). A clear example of how wrong a flashbulb memory can be is seen in the following excerpt from memory researcher Ulric Neisser:

> For many years I have remembered how I heard the news of the Japanese attack on Pearl Harbor, which occurred on the day before my thirteenth birthday. I recall sitting in the living room of our house—we only lived in that house for one year, but I remember it well—listening to a baseball game on the radio. The game was interrupted by an announcement of the attack, and I rushed upstairs to tell my mother. This memory has been so clear for so long that I never confronted its inherent absurdity until last year: no one broadcasts baseball games in December! (It can't have been a football game either: professional football barely existed in 1941, and the college season ended by Thanksgiving.)
>
> (Neisser, 1982, p. 45)

The consensus now is that, while flashbulb memories are prone to error, on the whole they are more detailed, accurate, and long-lasting than normal event memories.

Criteria for Flashbulb Memories

Flashbulb memories are different from normal memories, even if they are not perfect. Flashbulb memories are better records of the autobiographical experience of a surprising event but the memory itself may be more normal

(Tekcan et al., 2003). What we remember better is our reaction more so than the news itself. Flashbulb memories do have distinguishing qualities, at least phenomenologically (i.e., what they feel like when people remembering them).

So, in what circumstances are flashbulb memories more likely to be formed? An outline of the more important criteria was provided by Finkenhauer et al, (1998), which is one of the best accounts of flashbulb memories (Luminet, 2009) and is shown in Figure 12.5. The first criterion is that the event be novel. That is, it should be a rare and, most likely, a new occurrence. For example, seeing the World Trade Center towers being attacked was a new event, but hearing about a murder on the evening news is, sadly, not. This novelty can lead to a feeling of surprise. This uniqueness and unexpectedness helps it stand out in memory and so it is less likely to be influenced by interference. Also, because the event is surprising, people dedicate a greater degree of effort trying to make sense of the event and its consequences. This makes the flashbulb memory more complex and detailed as well as more enduring.

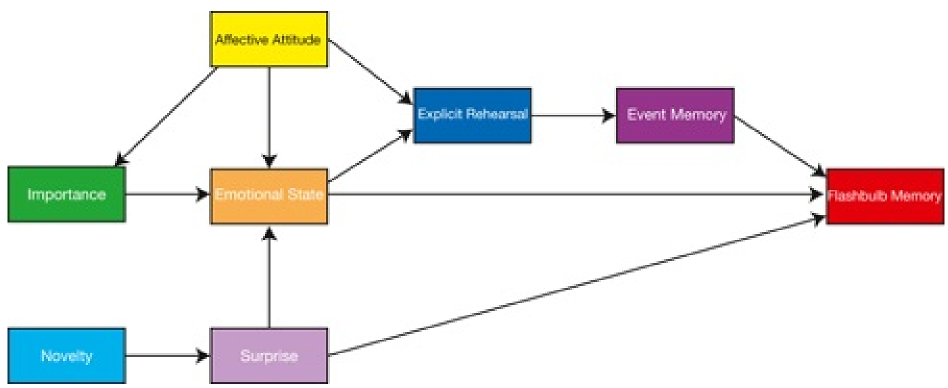

FIGURE 12.5 *Outline of Major Factors in the Creation of Flashbulb Memories*

Adapted from: Finkenhauer, C., Luminet, O., Gisle, L., El-ahmadi, A., van der Linden, M., & Philipott, P. (1998). Flashbulb memories and the underlying mechanisms of their formation: Toward an emotional-integrative model. *Memory & Cognition*, *26*, 516–531

Flashbulb memory creation requires that the event be important and have significant consequences for the people witnessing or hearing about it. It is critical to remember information that had an impact on our lives but not to remember more trivial information. For example, the events of September 11, 2001, were important and consequential but a penny found in a parking lot is not.

The degree to which the events are surprising and important affects people's emotional reactions. The more intense the reactions, the more likely a flashbulb memory will be formed. Emotionally intense events raise arousal levels, which can aid in memorization (Bradley, Greenwald, Petry, & Lang, 1992). Not all flashbulb memories are formed from negative events. They can also be formed from extremely positive events, such as the positive flashbulb memories that some Germans formed when the Berlin Wall came down (Bohn & Berntsen, 2007). That said, these positive flashbulb memories tend to be less accurate than the negative ones. Overall, emotional experience can lead to more attention to the event, more elaborative processing, and more reminding occurs as subsequent consequences are encountered. This all facilitates the retention of information in a flashbulb memory.

Emotional reactions can override the novelty and surprise components for events that are expected, even if they are repeated, but are emotionally intense. For example, a survey of gay men in the New York City area found that, although there were repeated experiences of loved ones dying of AIDS, and the death was expected with the progression of the disease, the emotional intensity of each experience was sufficient to create lasting memories of hearing of the death (Mahmood, Manier, & Hirst, 2004). Thus, emotional reaction plays a pivotal role in flashbulb memory formation.

Another factor that influences flashbulb memory formation is affective attitude. These are people's opinions and beliefs prior to an event that can provide the basis for later elaborative processing. If people lack the requisite knowledge to understand the event, a flashbulb memory is less likely to occur. For example, if a popular sports figure suddenly retires, people who are not fans of that sport will consider that news insignificant and not form a flashbulb memory. In contrast, a person who is an avid fan may form a flashbulb memory. In a study by Curci, Lanciano, Maddalena, Mastandrea, and Sartori (2015), Italians were found to be more likely to have formed a flashbulb memory of the unexpected resignation of Pope Benedict XVI if they were practicing Catholics than if they were Evangelicals or nonpracticing Catholics, although other normal event memories were similar across the groups.

Finally, people engage in more overt rehearsal of a flashbulb memory event by discussing it with others. When these kinds of events occur, people spend a great deal of time thinking about the event and how they heard about it, including discussing with others how they heard about it and their reactions to it. Also, if the event is public, the news media can devote intense coverage to it (Koppel, Brown, Stone, Coman, & Hirst, 2013). This dwelling on and sharing of the information affects memory. The memory traces are reinforced and strengthened, decreasing the likelihood that forgetting will occur, and it may be a form of overlearning.

Stop and Review

Memories of surprising and emotionally engaging events can lead to flashbulb memories that are resistant to forgetting. The original theory of flashbulb memories was that they were highly detailed, accurate, and durable. However, subsequent work has shown that they are prone to distortions and forgetting. Currently, flashbulb memories are viewed as being special, but not perfect. The creation of flashbulb memories requires a number of factors to be in place for them to occur, which is why they are so rare. These factors include elements of surprise, personal involvement and emotion, and rehearsal.

REMINISCENCE BUMP

Like most memories, autobiographical memories show a forgetting curve. People remember recent events better than older ones (Whitten & Leonard, 1981). Oddly enough, this forgetting curve extends to events that happened prior to birth (Rubin, 1998), which reflects an interest in historical events that led up to the current situation (Brown, 1990). There is a major deviation to the forgetting curve considered here, namely the very good memory for life experiences around the age of 20 (between 15 and 25), called the **reminiscence bump**. This is an interesting characteristic of autobiographical memory that is easier to observe as a person ages. In reminiscence bump studies, the Galton–Crovitz method is often used. In this paradigm people are given lists of words—such as “bird,” “chair,” “apple”—and are asked to recall the first memory from their lives that comes to mind. Most of the memories are from the recent past, and the further back in time one goes, the fewer memories there are, just as in a standard forgetting curve. However, there is a bump in the curve around the age of 20, with people recalling more information from this time than would be expected (see Rubin, Rahhal, & Poon, 1998). This reminiscence bump is shown in Figure 12.6.

This phenomenon is so pervasive that it even influences the life periods from which we derive the topics of our dreams (Grenier et al., 2005) and for information that is not strictly autobiographical, such as memories for famous sports figures (Janssen, Rubin, & Conway, 2012; but see Koppel & Berntsen, 2016). Other reminiscence bumps for strictly non-autobiographical information may occur as a function of what we were exposed to. For example, in a study by Krumhansl and Zupnick (2013), students at Cornell University were probed for memories of popular songs from various decades. What they found were reminiscence bumps for when people were around the age of 20, as well as another bump for when their parents were around the age of 20. The explanation is that the first bump is a normal reminiscence bump, whereas the second is due to often hearing their parents' preferred music (from when their parents were around the age of 20) when growing up.[2] There are a number of explanations for the reminiscence bump. These are covered next.

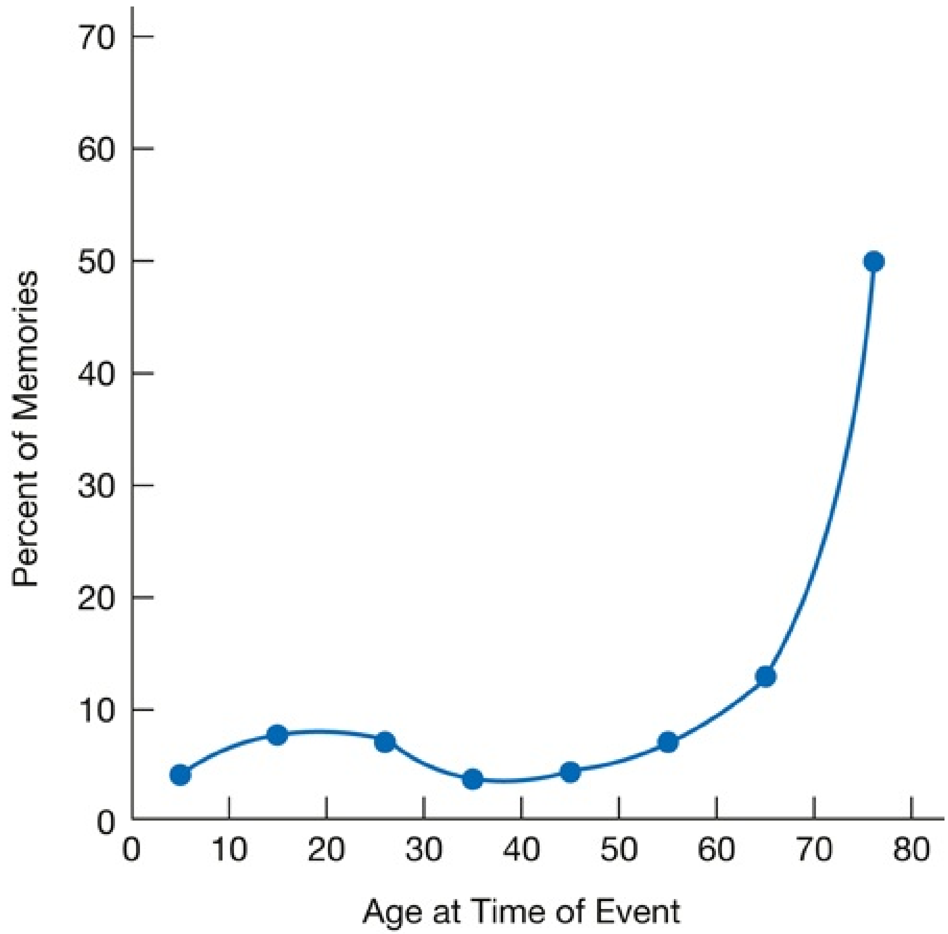

FIGURE 12.6 *The Reminiscence Bump*

An averaging of data reported in: Rubin, D. C., Rahhal, T. A., & Poon, L. W. (1998). Things learned in early adulthood are remembered best. *Memory & Cognition*, *26*, 3–19

Cognitive Mechanisms

One explanation for the reminiscence bump is oriented around basic cognitive processes. Serial position effects exist in long-term memory. Part of this is an autobiographical memory primacy effect for first experiences of a certain type. One of the things about the age around which the reminiscence bump is centered is that this is a time when there is a great deal of change and a number of experiences are occurring for the first time, such as one's first kiss, first car, first apartment, first job, and so on. Because there are so many firsts, it is not surprising that these memories are easier to recall. Thus, the reminiscence bump is partially due to a large number of primacy effects. Supporting this idea is the finding that people who immigrated to the United States from Spanish-speaking countries show reminiscence bumps at different times, depending on when they moved. The later they moved, the later the reminiscence bump. Moving to a new country with a new language provides a lot of novel first experiences (Schrauf & Rubin, 1998). More generally, older adults may divide their life into chapters marked by a series of beginnings and endings (Steiner, Pillemer, Thomsen, & Minigan, 2014). These beginnings and ends are more likely to be associated with instances of more new experiences than periods of time within one of these life chapters. Around 20 years of age, more people are beginning and ending chapters of their lives than at other ages.

Neurological Changes

Another explanation for the reminiscence bump is neurological. Around the age of 20 is when people are at their neurological peak, when their nervous system is neither maturing nor declining. As such, people are at their best capacity to encode and store memories. Thus, memory should be more efficient. Prior to this, people have difficulty encoding information into long-term memory. After this, one begins to see declines in some memory functions, which becomes more prominent as aging progresses.

Identity Formation

Another explanation for the reminiscence bump is that around the age of 20 is when people are making a number of decisions about who they are with regard to preferences, ideologies, vocation, and so on (Rathbone, Moulin, & Conway, 2008). Although we can make these decisions at any time during our lives, more decisions are made at this time. These are decisions that shape our future choices and our actions and choices become associated with them. A result of this is increased interconnectivity for memories from this time, making them more accessible.

Cultural Schemas

A final explanation for the reminiscence bump is that people have schemas or "life scripts" for the important periods and major transition points of their life (Berntsen & Rubin, 2004). In Western culture, this would be things like graduating from school, getting married, buying a house, having a child, and so on. People then organize their autobiographical memories using these schemas. When retrieving information, they use these schemas as a guide, thereby producing the reminiscence bump. In a study by Rubin and Berntsen (2003), college students estimated the likelihood that a typical 70-year-old would remember various life events. These students' estimates were very close to the actual pattern shown by older adults. Similarly, Bohn and Berntsen (2011) show that children exhibit a reminiscence bump for the future (projected) lives. This can be seen for both cultural life scripted and nonscripted events in Figure 12.7. Together this data suggests that cultural expectations guide the maintenance of information in autobiographical memory. We remember more from certain parts of our lives because our culture says that they are more important.

Because most of the events in cultural life schemas are positive (e.g., going to college, getting, married, having a baby, etc.), this may contribute to the bias for remembering more positive life events as time goes on (Berntsen & Rubin, 2002). Not surprisingly, this cultural life script account really only applies to events are (largely) positive and expected (e.g., getting a first job), but not to surprising and negative events (which are unplanned). These surprising events are often set apart and do not follow the reminiscence bump (Dickson, Pillemer, & Bruehl, 2011).

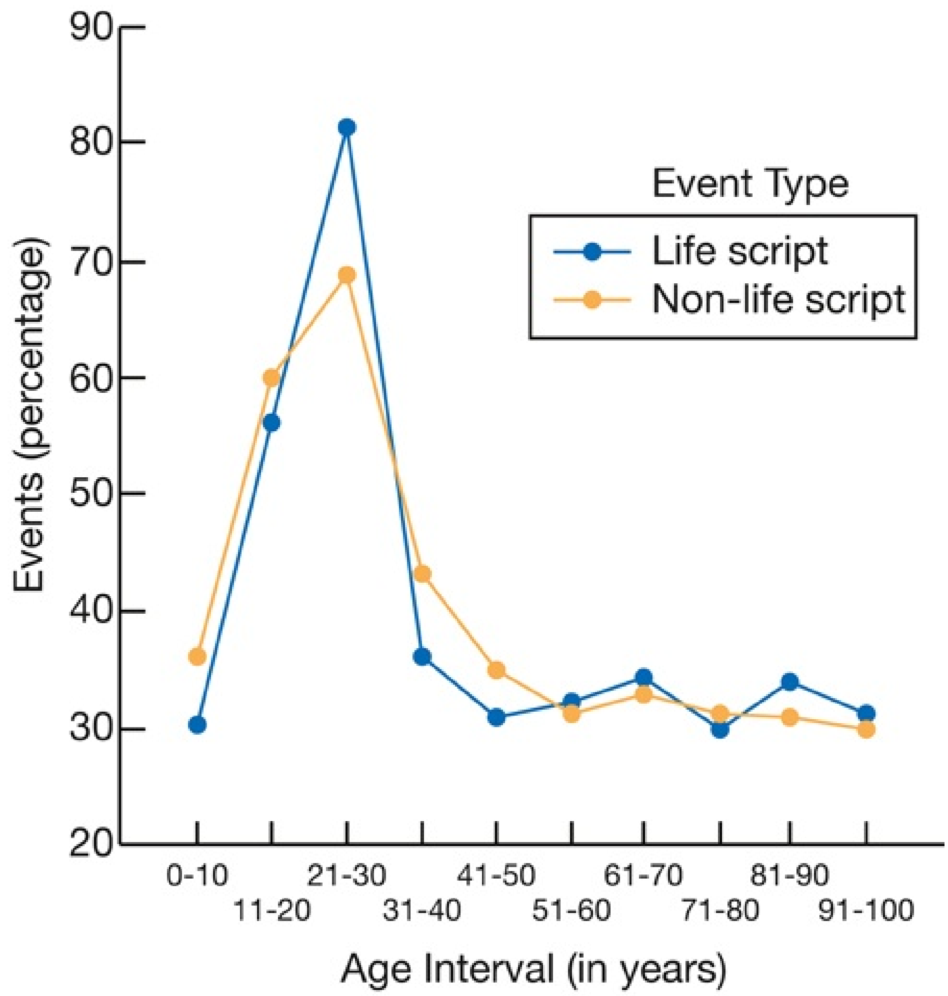

FIGURE 12.7 *Reminiscence Bumps for Future Life Events as Provided by Children (these Occur for Both Events That Do and Do Not Belong to a Culture's Life Script)*

An averaging of data reported in: Bohn, A., & Berntsen, D. (2011). The reminiscence bump reconsidered: Children's prospective life stories show a bump in young adulthood. *Psychological Science*, *22*(2), 197–202

Another source of support for life scripts is a study by Copeland, Radvansky, and Goodwin (2009; see also Koppel & Berntsen, 2014), in which people read a novel (*The Stone Diaries* by Carol Shields). This novel describes a person's entire life. When people were tested for memory of the novel, a reminiscence bump was found, even though this was a story about someone else's life. Retrieval was guided by a cultural schema and not by first events, neurological development, or development of one's self-identity, all of which are impossible in this case.

Stop and Review

The reminiscence bump is better memory for life events around the age of 20 than would be expected by a normal forgetting curve. There are several factors that play into this. The cognitive factors involve unique and initial experiences. The biological factors involve people being at their neurological peak. The identity formation factors involve the development of one's self-identity. Finally, cultural schemas dictate how life is supposed to progress and this influences what we remember from our lives.

PUTTING IT ALL TOGETHER

We are our memories. Your life story is your autobiographical memory. You construct this story into a coherent narrative to tell yourself and other people. You put your autobiographical memory together like a storyteller puts together a novel or play. Sometimes this story is recorded in a diary or autobiography, but more often it is just kept in our heads and our conversations. Sometimes it is something you are deliberately try to understand and convey and, other times, parts of the story involuntarily pop into your head.

Your autobiographical memory is assembled from various bits and pieces. It is reconstructive and interpretive. It is made up of facts and inferences. Some of these are the general facts of your life and some are the episodes and scenes from your experiences, the specific events, and general extended and repeated events. Parts of the story are also the general themes that run throughout. These are these of your education, careers, personal relationships, and so on.

You do not assemble your autobiographical story for your own amusement but to give purpose and meaning to your life. These are the reflective, social, ruminative, and generative functions. The particular life story you create out of autobiographical memory varies with what you are trying to do at the moment. You can shift your perspective around from the ones you had at the time, to those of other people, or even from your current perspective on past events. This reconstruction and these perspectives can be guided by current knowledge and biases, as well as a more stable understanding of the world from your scripts, schemas, and culture. These schemas can direct what parts of your life you favor and remember better than others. Part of the reason you will remember your late teens and early twenties so well is because this is a time of your life when lots of things are changing and happening for the first time. Moreover, our culture tells us that it where we should place our emphasis and we remember more from that time than would otherwise be the case.

That said, autobiographical life stories do not always follow the expected path but take twists and turns in response to the unexpected, unusual, and nonschematic events that happen. Sometimes the unexpected parts are so surprising, emotional, and consequential that they seem like they been burned into your memory, as with flashbulb memories. It is an interesting story.

Things happen. You react. Some things are good for us and some of them are bad. While life has pain and suffering, it also has happiness and joy, fear and anger, love and hate. These emotions are a critical part of who you are and how you use autobiographical memory, and they make the story more engaging. If autobiographical memories are positive, they are general and broad, but when they are negative, they are more focused. Overall, as your autobiographical memory and story develops, the older material takes on a more positive spin. Your life gets better.

STUDY QUESTIONS

1. In what ways are autobiographical memories like episodic memories? Like semantic memories?
2. How quickly can people retrieve autobiographical information? How does this compare to information learned in the lab? What does this tell us about autobiographical memories?
3. What are some special ways for assessing the autobiographical memories?
4. What are some of major functions for autobiographical memory in mental life?
5. What are the three levels of autobiographical memory? What are their characteristics?
6. What sort of neurological evidence supports the idea that there are different levels of autobiographical memories?
7. In what ways is autobiographical memory like a story or narrative? How does this affect how autobiographical memories are remembered?
8. What are the two types of perspectives that that occur in an autobiographical memory? What sorts of factors influence which of these two occur?
9. What is better remembered from autobiographical memories, the schema-consistent or inconsistent details? What theory accounts for this and how?
10. What role does emotion play in the creation and maintenance of autobiographical memories?
11. What are involuntary memories, and what are their characteristics? How do these relate to our understanding of PTSD?

12. What are flashbulb memories? What causes them? How much are they like or dislike regular memories?
13. What is the reminiscence bump? Why does it occur?

KEY TERMS

- autobiographical memory
- diary studies
- event-specific memories
- field memories
- flashbulb memories
- Galton–Crovitz cue word method
- general events
- generative function
- involuntary memory
- life narrative
- lifetime periods
- Pollyanna principle
- positivity bias
- reflective function
- reminiscence bump
- ruminative function
- schema-copy-plus-tag model
- observer memories
- social function
- tunnel memory

EXPLORE MORE

Here are some additional readings that so that you can more deeply explore topics in autobiographical memory.

Berntsen, D. (2009). *Involuntary Autobiographical Memories: An Introduction to the Unbidden Past*. Cambridge: Cambridge University Press.

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NOTES

1 See Kvavilashvili and Mandler (2004) for a similar idea for semantic memories and Jakubowski, Farrugia, Halpern, Sankarpandi, and Stewart (2015) for spontaneously having songs pop into our heads.
2 See Svob and Brown (2012) for an account of how experiences in warfare conflict can be passed from one generation to another.

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CHAPTER 13

Memory and Reality

Our memory is our contact with the world beyond the present. We make assessments about the nature of reality, how it works, and what has happened in the past based on what we remember. Most of the time our memories are fairly accurate and we get along fine. However, other times, what we remember and what actually happened may differ. For example, if you misremember that you turned off the oven before you left for vacation, when in reality you left it on, you risk burning down your house, or at least a much larger utility bill. It is important to understand when our memories can betray us and when they can be trusted. What are the circumstances that cause memory and reality to part ways?

In this chapter we discuss a number of factors related to how memory and reality square up. The first issue is how we keep track of where our memories come from, or source monitoring, which includes situations of unconscious plagiarism, or cryptomnesia, and false fame effects. We also examine the sleeper effect and how this affects our attitudes and opinions. We then move on to cases where we remember things that never happened, also called false memories. This includes implanted memories and memories recovered under hypnosis. Finally, we look at how the normal use of information in memory can change our memories, as with verbal overshadowing, the revelation effect, and memory blending.

SOURCE MONITORING

Many of the issues that we have seen so far have been on what a memory is about. While this is important, another critical factor is knowing *where* a memory came from. For example, was a story on the news or from a friend? Was it all just a dream? The ability to keep track of where memories come from is **source monitoring**[1] (Johnson, Hashstroudi, & Lindsay, 1993) and it involves processes over and above those used to assess whether something is old or new (Johnson, Kounios, & Reeder, 1994). However, as complex as it is, source monitoring does not necessarily require complete conscious awareness of the original source. Accurate source judgments are regularly made using vague and partial information associated with less conscious feelings of familiarity (Meissner, Brigham, & Kelley, 2002).

Source monitoring requires people to take source and content information and integrate them into a common memory trace. Later there is an active search of memory for source information. Each of these stages involves a different part of the brain. The integration of information involves the hippocampus. In comparison, the search for source information, being a controlled memory process, involves the frontal lobes and posterior hippocampal activities (Davachi, Mitchell, & Wagner, 2003), whereas the actual retrieval of that information emphasizes the temporal lobes (Senkfor & Van Petten, 1998), as well as the parietal lobes when there is conscious recollection (Leynes & Phillips, 2008).

Types of Source Information

Different types of information are used to evaluate the source of a memory. Again, people can make fairly accurate judgments based only on partial or unconscious information (Hicks, Marsh, & Ritschel, 2002). One criterion is **perceptual detail**. This is perceptual information that is encoded into a memory, such as what a person was looking at or hearing at the time. Memories for events that were actually experienced often have more perceptual detail than those created from hearing about an event from someone else or imagining it. For example, people find it easier to discriminate between words they actually said and words that they only imagined saying. The difference in perceptual experiences in these two cases is pronounced. However, people find it harder to remember words that another person actually said than to “hear” the words in their mind as if they were spoken by that person (Johnson, Foley, & Leach, 1988). This is because they have similar perceptual or pseudoperceptual qualities.

Another criterion is **contextual information**. This is information about the context in which a memory was acquired. For example, if people remember seeing a plane crash while they were at an airport it is more likely that the event was witnessed. However, if people remember seeing the plane crash while they were sitting in their living room it is more likely that they saw it on the news. Thus, people can use expectancies based on the context to help make source monitoring decisions (Bayen, Nakamura, Dupuis, & Yang, 2000; Küppers & Bayen, 2014).

Overall, people better remember source information when the source is consistent with expectations than if a memory is from an unexpected source, suggesting that some guessing is involved (Bayen et al. 2000). These expectancies are more likely to be operating at retrieval than at encoding (Hicks & Cockman, 2003). For example, it is easier to recall that a reminder to call your mother came from your sister than from your professor because the first is more expected, even if the second were true. People can also be swayed by what others say. For example, if you know that other people have claimed to have witnessed something, you are more likely to make a source monitoring error and claim to have seen something that you only imagined (Hoffman, Granhag, See, & Loftus, 2001). Source monitoring is a complex and fragile memory process.

A third criterion is the amount of **semantic detail** and/or **affective information** available. This is how much people were mentally and emotionally involved in events. This can include thoughts that people have (e.g., "man, Bob must really be stupid to ask if gravity's getting heavier") or emotional reactions (e.g., "I remember feeling really queasy when I saw what the car accident had done to that girl's face"). This information can be used to help figure out where a memory came from. It should be noted that source information is less likely to be bound to an emotional memory (Cook, Hicks, & Marsh, 2007), perhaps because emotional responses tend to focus our attention on the central object and less on the context or source. This is especially true if source information provides us insight into misbehaving people, such as if they are cheaters (Bell et al., 2012), as shown in Figure 13.1.

A final criterion is **cognitive operations**, the mental processes done when first thinking about information. This includes retrieving information from long-term memory, manipulating it, trying to generate a mental image, and so on. This is more likely to be found in memories of things that were only thought about. When we think about things, we remember not only what we were thinking about but also the mental activity that we used to generate those thoughts. For example, if you were trying to remember something your significant other said in the middle of an argument, you might think was this (1) a real argument or (2) something you imagined he or she said when you couldn't talk directly to him or her (most people seem to be brilliant at winning these arguments). An imaginary argument would have more cognitive operations associated with it. Source memory may sometimes show a generation effect (see Chapter 3) and be better for information that people actually generated (because of the stored cognitive operations) than something that was simply read (Geghman & Multhaup, 2004).

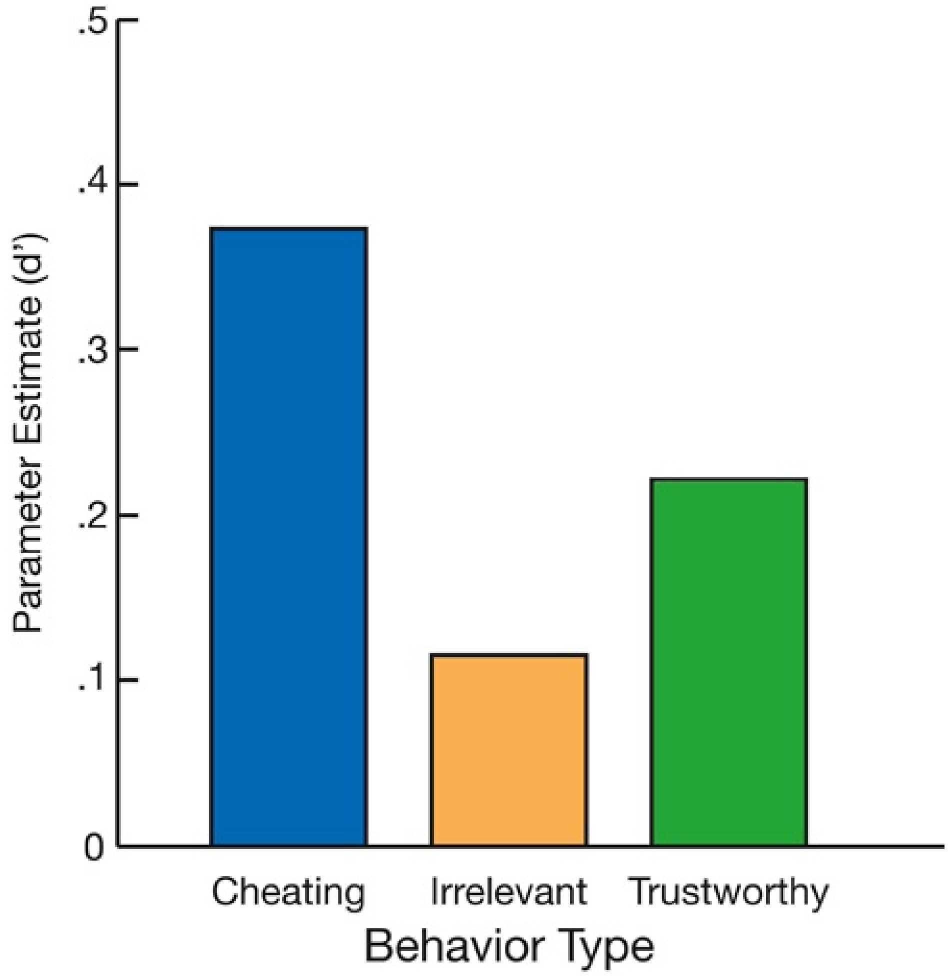

FIGURE 13.1 *Superior Source Memory for Cheating as Compared to Other Behaviors*

Adapted from: Bell, R., Buchner, A., Erdfelder, E., Giang, T., Schain, C., & Riether, N. (2012). How specific is source memory for faces of cheaters? Evidence for categorical emotional tagging. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *38*(2), 457–472

Types of Source Monitoring

There are three types of source monitoring (Johnson et al., 1993): internal source monitoring, external source monitoring, and reality monitoring. Table 13.1 provides a summary of each to help orient you.

Internal source monitoring involves distinguishing between actions people either thought about or actually did. People who are trying to remember if they locked the back door before going on vacation are engaged in internal source monitoring. Perceptual detail is important for these decisions because actions actually taken have more perceptual details in memory (e.g., remembering seeing the key turning in the lock), whereas events that were only thought about may have fewer. A similar point can be made for context information. Semantic detail and emotional reactions are likely to be low because these actions were generated by people and so are unlikely to be reacted to. Finally, cognitive operations are likely to be high in both because the people are planning to carry out the action. The question is whether it was done.

As an example of internal source monitoring, Foster and Garry (2012) had students at Victoria University of Wellington assemble a toy vehicle by following a plan. During the assembly, the participants did some of the steps but not others. Those steps not taken were done by an experimenter while the student's eyes were closed. What is interesting is that people were more likely to make internal source monitoring errors when they could see all of the pieces laid out during the building process than when they only saw the pieces they needed for the current step. The additional perceptual information from consistently seeing the pieces and imaging how they would be assembled into the toy increased the possibility of an internal source monitor error.

A second type of source monitoring is **external source monitoring**, in which people distinguish between two external sources. Who told you this, Susie or Jane? Did you read about this in a newspaper or a supermarket tabloid? Perceptual detail is important because different external sources have different perceptual details (e.g., a man's voice or a woman's voice). Contextual information can also be informative. For example, imagine deciding which of two people told you something. If you always see one person in your neighborhood and the other person on campus, then knowing where you heard something can help you narrow it down. Semantic detail and emotional reactions can be used in a similar fashion. Finally, because the information is coming from outside of people, cognitive operations are likely to be low and not very informative for source memory. Another factor that can influence external source monitoring is whether the source was involved in the described event. For example, you might hear about a train wreck from someone who was actually on the train or from a news reporter. In general, people remember source information more accurately when the source was actually involved in the event (de Pereyra, Britt, Braasch, & Rouet, 2014).

TABLE 13.1 *Types of Source Monitoring and how They Relate to Different Types of Source Information*

Type	Perceptual Detail	Contextual Information	Semantic Detail	Emotional Reactions	Cognitive Operations
Internal	+	+	–	–	–
External	+	+	+	+	–
Reality	+	+	+	+	+

Reality monitoring (Johnson & Raye, 1981) involves distinguishing between memories of events that actually happened and those that were only imagined. For example, did witnesses to a car accident actually see broken glass or did they only hear someone speak of broken glass later? It is more common for people to mistakenly think they saw things that were only imagined and less common to think that something that was seen was only imagined (Belli, Lindsay, Gales, & McCarthy, 1994; Henkel, 2012). Note that people are less likely to make reality monitoring errors for emotionally charged information (Kensinger & Schacter, 2006).

Perceptual detail is important in reality monitoring. Real events have more perceptual details than imagined events. Moreover, real event memories have more contextual information than memories of imagined events. Semantic detail and emotional reactions are more developed in memories of real events. Lastly, knowledge about cognitive operations is scarcer for real events but is more plentiful for imagined events. Still, reality monitoring errors do occur. For example, in a study by Intraub and Hoffman (1992), a week after viewing photographs and reading descriptions of scenes, people made frequent mistakes by identifying pictures of scenes they had only read about as having been seen but made fewer mistakes of claiming that scenes which they had viewed were only read about.

Source Monitoring Errors

Source monitoring is pertinent for this chapter because source information grounds our memories in reality. Often, people are reasonably accurate about knowing where their knowledge came from. However, errors can be made. For example, repeated attempts to remember, which can produce reminiscence and hypermnesia, can also increase the likelihood of confusing an imagined event for a real one (Henkel, 2004). This is because the repeated memory retrievals of imagined information may introduce perception-like qualities to the memory (through the process of imagination) and make a memory seem more like something that actually happened.

When source monitoring errors occur, people's understanding of the world and what actually happened are at odds. As one example, if there is an error in internal source monitoring, people might believe they had done something that was actually not done. As another example, people may believe that they read some fact about a president of the United States in a history book when, in reality, they had watched a historical movie.

PHOTO 13.1 *Source monitoring is an important part of how we use our memories—we not only need to know the "what" of memory content, but also the "from where" (for example, if you know a secret, it would be a good idea to know from whom that secret came in order to avoid embarrassment)*

Source: David Buffington/Blend Images/Thinkstock

Source misattributions can be biased to make ourselves look good. In a study of choice making (Mather, Shafir, & Johnson, 2000), people had to choose between two alternatives—for example, which of two people they would go out with on a blind date. A number of characteristics for each person were given. Some were positive, such as "always interesting to talk to," and others were negative, such as "awkward in social situations such as parties." Sometime after picking someone, people identified which characteristics belonged to which dating prospect. In general, people tended to misremember positive characteristics of the other choice as belonging to the one they picked and, to a lesser extent, tended to misremember the negative attributes of the person they picked as belonging to the person they rejected. This does not occur when options are assigned rather than chosen (Mather, Shafir, & Johnson, 2003). So, our choices can distort our memories. We have a tendency to think of the things we choose as being more positive than they are and the things we do not choose as being more negative than they are.

TRY IT OUT

This Try It Out section is for studying the processes of source monitoring. As a reminder, there are also three basic types of source monitoring: internal, external, and reality monitoring. You can do whichever version you find the most interesting.

First, create a list of 40 five- to seven-letter two-syllable nouns. Then, randomly assign these words to two conditions that we'll call conditions A and B. Have 12–24 people go through the list, presenting the words in one of the three ways described below. At the end of the list, give people a distractor task to do for five to 10 minutes to occupy their time. For example, you could have them solve math problems to help allow some forgetting to occur. At the end of the distractor period, give your participants the entire list of 40 words and have them indicate which source the word originated from. After you collect your data, average the number of correct responses for each source type. What you should find is that people make source monitoring errors.

For internal source monitoring, have people read 20 of the words out loud and have them read 20 of the words silently to themselves. For the memory test, have people indicate whether the words were actually said or just imagined. Most of the source monitoring errors should be cases where people say that words they only imagined were actually said.

For external source monitoring you will need two experimenters (if they are of the same gender, then that is even better). Have the experimenters alternating turns reading the words aloud, with one person reading 20 words and the other reading the rest. For the memory test, have participants indicate which words were said by which person.

For reality monitoring, as the experimenter, read 20 of the words aloud and have your participants imagine the other 20 words being said in your voice. For the memory test, have them indicate whether the words were actually said or just imagined. Most of the source monitoring errors should be people reporting that words they only imagined were actually said.

Cryptomnesia

Knowing where information comes from can have important consequences. For example, it is important to know whether an idea is your own or someone else's. When we present someone else's idea as our own, it is plagiarism, but not all plagiarism is intentional. Some plagiarism is unconscious and unintentional. It occurs when people come up with ideas they believe are their own but in fact were encountered in the past. This unconscious plagiarism is called **cryptomnesia** (Gingerich & Sullivan, 2013; but see Brown & Halliday, 1991). There are several theories regarding how cryptomnesia occurs. One is that it is a reality monitoring error. People retain the content information in memory but, because of the amount of time that has passed, and/or because little attention was paid during the original encoding, the memory is weak and the source information has little or no influence later. Memories of plagiarized ideas have many of the same phenomenological characteristics as accurate memories. As such, the feeling of familiarity produced by a plagiarized memory only boosts people's confidence in the idea (Brédart, Lampinen, & Defeldre, 2003).

Another way that source monitoring errors produce cryptomnesia is by having people take existing ideas and elaborate or improve on them (Stark & Perfect, 2006). For example, people might try to think of novel uses for an object, like a brick. Then, during an elaboration phase, people try to improve on the ideas, both their own and those of other people. By elaborating on the information, there are now memories for cognitive operations associated with each idea and so another person's idea seems more like something people would have thought of themselves, rather than something that was heard from someone else. This cryptomnesia gets worse the more people elaborate on the ideas (Stark & Perfect, 2008). This is why people working in groups where everyone is generating ideas, and trying to improve on each other's ideas, may later lead to people misremembering which ideas were generated by other people, and thus cause them to engage in cryptomnesia.

False Fame

A powerful way to manipulate memory is to influence the frequency that something is encountered. Information that is repeatedly encountered is more likely to be remembered and may become overlearned and become chronically available (see Chapter 7). However, different components of a memory are forgotten at different rates. Information content may be remembered for a long time but source knowledge may be lost. People may need to reconstruct this missing information, perhaps by assessing how familiar the memory seems. A source monitoring error that is familiarity-based is the **false fame effect** (Jacoby, Kelley, Brown, & Jasechko, 1989). This is the tendency to think that people are famous, or more famous than they really are, because their names are familiar. For example, you may think that your favorite musicians or actors are more widely known because they are well known to you. The false fame effect is even more dramatic in that it may be possible to take people who have utterly no fame whatsoever and make them "famous" overnight. This is done using the principle of mere exposure (see Chapter 6).

To study the false fame effect, a researcher might give people a list of names. Some names are of people who were mildly famous. These are names that most students might recognize but couldn't quite remember who they are. The other names on the list are people who are not famous, such as Sebastian Wiesdorf, Larry Jacoby, and Gabriel Radvansky. The task is to go through the list and pick out who is famous and who is not. Later, people would be given a new list of names consisting of famous people, nonfamous people whose names were seen before, and new nonfamous names. Half of the people would be given this new list immediately after the first, but the other half on the next day. People who got the second list the next day are twice as likely to call nonfamous people famous simply because they had seen those names earlier but forgotten where they saw them. Thus, those names became famous overnight!

This false fame effect can occur if people are distracted during encoding by another task (such as listening to a series of numbers, waiting for three odd numbers in a row) (Jacoby, Woloshyn, & Kelley, 1989). Because the name was familiar, people say that it is famous. Thus, the link between memory content and source is disconnected (Steffens, Buchner, Martensen, & Erdfelder, 2000). There is an unconscious influence of previous memories (this name was encountered before) on conscious efforts to make a decision (is this name famous?). This is one reason why some people say that there is no such thing as bad publicity. People may remember that they've encountered a name before but not why. The more times a name is seen or heard, the more familiar it is and the more famous that person seems. (It's not a good idea to overdo it. Eventually people connect the unflattering information with a name, as with the name Hitler.)

Social Influences and the Sleeper Effect

Memory for source can also be affected by social factors. One example of this is the influence of social stereotypes. When asked to remember from whom a set of statements came from, people who forget the appropriate source misattribute statements to people based on social stereotypes (Bayen et al., 2000). For example, people are more likely to attribute the statement “I’ll come talk to you as soon as I wash up” to a doctor and the statement “I had a deposition yesterday” to a lawyer, even if the opposite were true.

A phenomenon in social psychology that involves source monitoring is the **sleeper effect** (see Kumkale & Albarracín, 2003). This occurs when people are given some propaganda from a source of either high or low credibility. A high-credibility source might be scientist and a low-credibility source might be a member of the Ku Klux Klan. If the source has low credibility, then people initially discount it. However, after a few days, weeks, or months people still remember the information but now consider it more credible than before. What previously seemed unreasonable has, with the simple passage of time, become reasonable (Hovland & Weiss, 1951). The sleeper effect is shown in Figure 13.2, which conveys how much people’s attitudes toward ideas changed after hearing opinions from high- and low-credibility sources, both immediately and after a four-week delay. The sleeper effect occurs when people remember the content of a message but forget the source or, at least, the source information in memory becomes disconnected from the content. As a result, people are more willing to accept ideas because they no longer have the source information that would make it suspect (Underwood & Pezdek, 1998).

Several components must be in place to get a sleeper effect. First, people must pay attention to the message to set up a memory trace of the content. Second, the message source should be discounted after the message was given, preventing people from discounting the message from the outset and not learning it. Finally, people should evaluate the trustworthiness of the source immediately afterward. This provides more time for the source information to be forgotten (Pratkanis, Greenwald, Leippe, & Baumgardner, 1988).

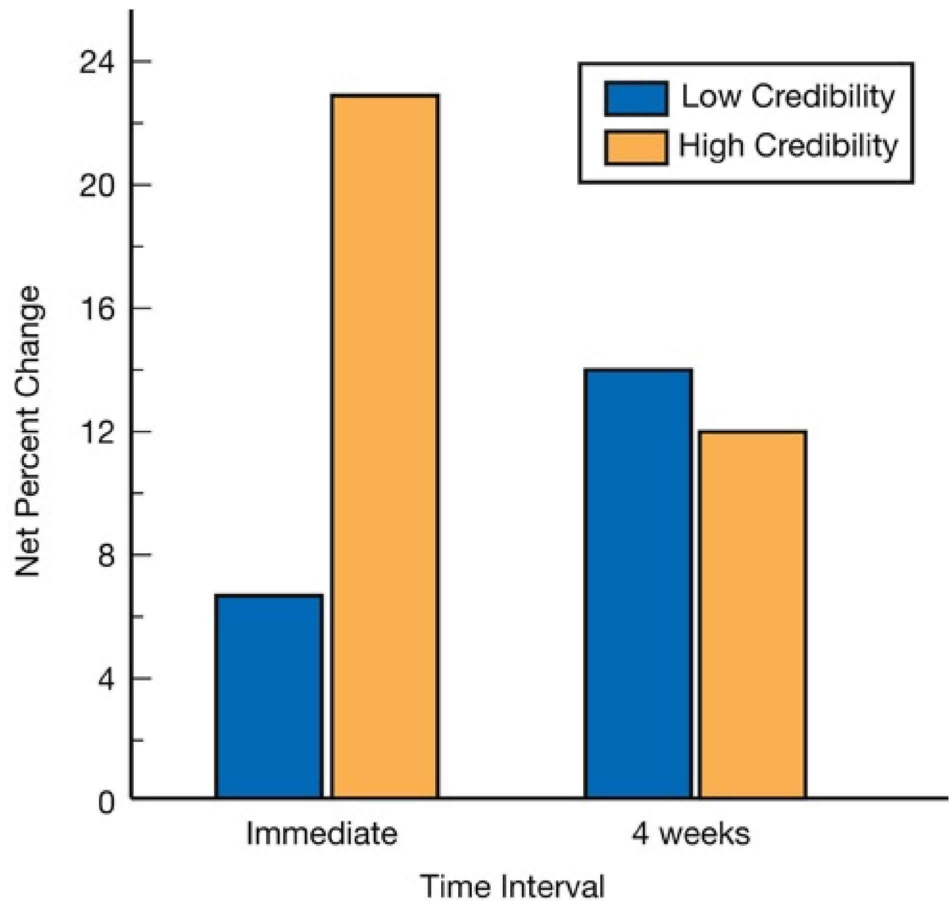

FIGURE 13.2 *An Illustration of the Sleeper Effect*

Adapted from: Hovland, C. I., & Weiss, W. (1951). The influence of source credibility on communication effectiveness. *Public Opinion Quarterly*, *15*, 635–650

A related finding is the **wishful thinking bias**, which is a tendency to misremember desirable information as having come from reliable sources and undesirable information as having come from unreliable sources (Gordon, Franklin, & Beck, 2005). This is especially true for information that has implications for yourself (Barber, Gordon, & Franklin, 2009). For example, if you hear someone say about you “boy, she is really smart” you are more likely to misremember this statement as having been said by a reliable source, such as your professor, as compared to a less reliable source, such as your bus driver, even if the opposite is true. And this is even more likely because it was a positive statement about you and not someone else. The opposite is true for negative statements.

Stop and Review

In addition to remembering information content, it is helpful to know where memories came from. This is source monitoring. People use various types of information to make source memory decisions. This can include perceptual details and contextual information in the memory, semantic detail and affective responses, and any cognitive operations about what they were thinking at the time the memory was created. Source monitoring includes discriminating between multiple external sources (external), whether one thought something or actually did it (internal), or if some event actually happened or was just thought about (reality). Although people are reasonably accurate at source monitoring, errors can occur, as with unconscious plagiarism (cryptomnesia), false fame, and sleeper effects. In all of these cases, people remember the content information but forget where it originated from.

FALSE MEMORIES

An important issue about remembering is when people "remember" things that never happened. These are **false memories**. Sometimes false memories can cause serious problems. A good example is erroneous information from eyewitness testimony.

Deese–Roediger–McDermott (DRM) Paradigm

A simple way to create false memories is by using a list-learning paradigm. This paradigm is so regularly used by memory researchers that it is commonly known as the **DRM paradigm** after the first researchers to describe it, Deese (1959) and Roediger and McDermott (1995), hence DRM. First, people hear a list of words, such as those in Table 13.2. Soon after, they try to recall as many of those words as possible. Of course, people typically recall only part of the list. The interesting thing here is that people often systematically misremember words that were not on the list. For example, for the list in Table 13.2, people often mistakenly say that they heard the word "sleep" even though it was not there (Gallo, 2010). This process of activating information and creating false memories can occur in as little as four seconds (Atkins & Reuter-Lorenz, 2008), suggesting that we create false memories as we actively comprehend the world around us.

TABLE 13.2 *Words that May Lead to a False Memory for the Word "Sleep"*

bed	rest

awake	tired
dream	wake
snooze	blanket
doze	slumber
snore	nap
peace	yawn
drowsy	

Source: Roediger & McDermott (1995)

False memories occur more frequently when there is a plausible context. People are likely to misremember the word "sleep" because all the other words in the list are strongly associated with the concept of sleep (Cann, McRae, & Katz, 2011). In general, these false memories are guided by how many associations there are between the words that were actually seen (the more the better), as well as the general recallability of the actual list words (the fewer the better) (Roediger, Watson, McDermott, & Gallo, 2001). A larger number of associations makes it more likely that a false memory word will be primed or unconsciously activated. The less recallable the actual items are, the more likely people will do some guessing or memory reconstruction, making it more likely that a false memory item will be "remembered." These false memories are based on partial information (Heit, Brockdorff, & Lamberts, 2004). For example, people may misremember the source (it was thought about but not heard) or may use more gist than verbatim memories (Brainerd, Payne, Wright, & Reyna, 2003; Brainerd, Wright, Reyna, & Mojardin, 2001). Because memories for pictures are much more detailed and less gist oriented, they are less likely to show this effect (Hege & Dodson, 2004).

TRY IT OUT

For an assessment of false memories, you can do a DRM study. First generate lists of 15 words each that have an unmentioned word with which all of the others have a strong association. You can use the "sleep list" shown in Table 13.2 or one of the other three lists provided below. For even more lists you can go to the library and look up Roediger and McDermott's (1995) paper, which has an appendix at the end with several lists of this type.

Once you have your lists of words, read aloud to people each list of 15 words. Read these words one at a time at a rate of about one second per word.

When you are done reading, give each of your participants a sheet of paper. For each list, have people try to recall as many words as they can remember by writing them down on the paper. This can be done individually or in groups, but you should have at least 24 participants.

After the participants are done recalling, go on to the next list. Once they have gone through all of the lists, collect their response sheets. From the response sheets get the proportion of the words that were actually heard that were remembered later. You may also want to keep track of from where on the original list the words that were actually remembered came. Were they from the beginning of the list, the middle, or the end? Also, tabulate the number of false memories that occurred. That is, determine the proportion of the lists that resulted in people reporting a false memory. You might also want to keep track of in what part of their recall output the false memory was reported. Was it near the beginning, in the middle, or near the end? What you should find is that most of these false memories occurred toward the end.

Bread: butter, food, eat, sandwich, rye, jam, milk, flour, jelly, dough, crust, slice, wine, loaf, toast

Needle: thread, pin, eye, sewing, sharp, point, prick, thimble, haystack, thorn, hurt, injection, syringe, cloth, knitting

Soft: hard, light, pillow, plush, loud, cotton, fur, touch, fluffy, feather, furry, downy, kitten, skin, tender

This DRM false memory effect is supported by ERP measures. At encoding, compared to when people will remember accurately, when there will be false memories, the neural ERP signal suggests that during encoding people are paying less attention to the details of the real information (Urbach, Windmann, Payne, & Kutas, 2005). fMRI recordings have found that false memories are associated with more activity in brain areas used for mental images (see a description of imagination inflation later), particularly the anterior cingulate cortex (BA 24), precuneus (BA 7), and right inferior parietal lobe (BA 40) (Gonsalves et al., 2004).

At retrieval, the P300 component of an ERP signal occurs *about* 300 ms after people are given a memory probe and is associated with recognition. With false memories, the P300 is observed earlier than with true recognition (Miller, Baratta, Wynveen, & Rosenfeld, 2001). Also, there is less gamma activity during the recall of false memories, particularly in the hippocampus and left temporal lobe (Sederberg et al., 2007). Overall, this suggests that people are making memory decisions faster as if they are being less thorough and using less information.

This creation of false memories is influenced by a number of factors. One is the operation of inhibition (see Chapter 8), which is involved in directed forgetting (Kimball & Bjork, 2002). When people are asked to forget a set of words that regularly elicits a false memory, then the rate of producing false memories increases. Apparently, the instruction to forget inhibits the memory for that list, thereby making access to memories for the entire list harder. As a result, people have trouble discriminating between what was actually heard and what was not. So, more false memories are produced. In other words, trying to forget what was actually heard before makes it harder to distinguish reality from imagination.

False Memories from Integration

Another way people can misremember is when information that was presented at different times is integrated into a single memory. With integration, what were actually several events are misremembered as one. This may involve the schema integration processes discussed in Chapter 9. People may misremember different pieces of information as being part of the same event if they "seem" like they should go together.

One example of integration is a study by Bransford and Franks (1971), in which people heard a list of sentences, shown in Table 13.3. As they were listening, people had to answer questions about the sentences, also shown in the table. (Go ahead and read the sentences and answer the questions now.) Afterward, people identified which sentences they had seen and rated their confidence in their memory. A portion of this recognition test is shown in Table 13.4. Try to identify which sentences you remember seeing and which you do not. Also, rate how confident you are. After you are done this, look back at Table 13.3 to see which sentences were actually there.

The important thing here is that the study and test sentences varied in the number of simple idea units (called propositions) they had, which could be one, two, three, or all four propositions. For example, one sentence, "the ants were in the kitchen," is a one-proposition sentence, "the ants in the kitchen ate the jelly" is two, "the ants in the kitchen ate the jelly, which was on the table" is three, and "the ants in the kitchen ate the sweet jelly, which was on the table" has all four propositions. On the memory test, the more propositions a test sentence had, the more likely people "remembered" it. A sentence with four propositions that was not read was more likely to be "recognized" than a sentence with only one proposition that was actually read. Moreover, confidence ratings showed the same pattern and increased with the number of propositions, as shown in Figure 13.3.

The explanation for this is that when people hear the sentences, because there is overlap in content, the sentences are likely to be interpreted as referring to a common situation. This makes their integration easy. This integrated representation is then used to make memory judgments. Items that contain more propositions more closely match the memory trace and so are more likely to be recognized and given higher confidence ratings. People use memories of entire events that they created, not memories for what they actually experienced.

TABLE 13.3 *Sentences Used in the Bransford and Franks (1971) Study*

The ants ate the sweet jelly, which was on the table	The ants ate what?
The ants in the kitchen ate the jelly, which was on the table	The ants were where?
The ants in the kitchen ate the jelly	What was in the kitchen?
The ants ate the sweet jelly	The jelly was what?
The ants were in the kitchen	What was in the kitchen?
The jelly was on the table	What was on the table?

TABLE 13.4 *Recognition Test from the Bransford and Franks (1971) Study*

The ants in the kitchen ate the sweet jelly, which was on the table
The ants in the kitchen ate the sweet jelly
The ants ate the sweet jelly
The sweet jelly was on the table
The ants ate the jelly, which was on the table
The jelly was sweet
The ants ate the jelly

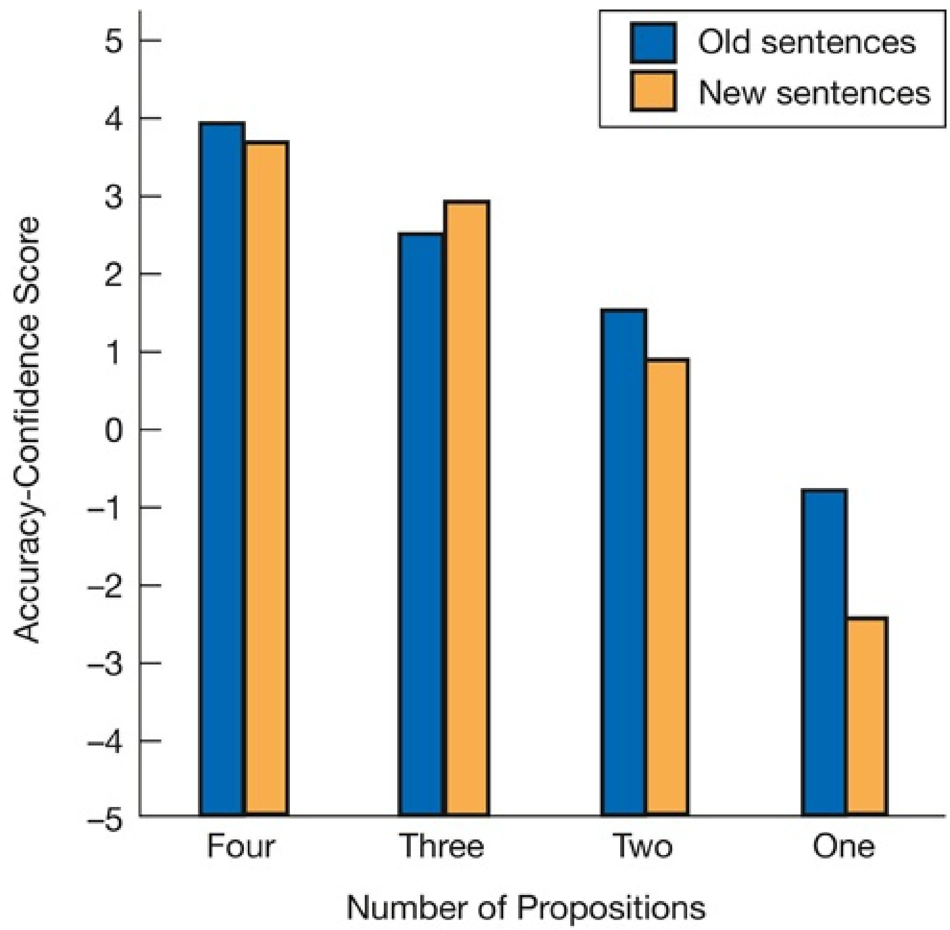

FIGURE 13.3 *Recognition Test Data from the Bransford and Franks (1971) Study—the Accuracy Score Reflects the Combined Influences of People's Selection on Items Along with Their Confidence in Having Heard Items Before*

Adapted from: Bransford, J. D., & Franks, J. J. (1971). The abstraction of linguistic ideas. *Cognitive Psychology*, *2*, 331–350

Stop and Review

The separation of memory and reality is most salient when people have false memories for events that never happened. In the DRM paradigm, people regularly report remembering words that were not actually encountered. This happens because the critical false memory word is strongly associated with the ones that actually occurred. This is supported by both behavioral and neurological data. False memories also come about through our natural impulse to integrate information that is about a common event. As a result, we lose our memories for the individual encounters and misremember what individual pieces were learned apart from the others.

IMPLANTED MEMORIES

In the preceding examples, false memories were created as a consequence of thinking about information. The false information was never explicitly conveyed. However, it is possible to have false memories implanted in a person, intentionally or unintentionally, from some outside source (Loftus, 2004). In these cases, information about some event is introduced to people in a way that leads them to adopt the memory as a real event from their lives.

For example, imagine that I tell you that your mother says that when you were eight years old you got lost in a mall. I then, over a stretch of time, repeatedly ask you if you remember that incident. The repeated attempts to remember would cause you to try to imagine this event and you start to confuse your imagination with reality. Alternatively, if you hear me say that I remember a story about whales on the news, you might later misremember reading the story on the internet (Meade & Roediger, 2002). This is because you remember something about a whale story and you know that you read lots of things on the internet. You put these two things together to form a false memory. Finally, if you are told that, as a child, you had an unpleasant experience with an item food that you don't eat often (e.g., egg salad), you then avoid that food in the future, as if you had a real taste aversion experience (Bernstein & Loftus, 2009; Scoboria, Mazzoni, & Jarry, 2008). Here, the imagining of the described event eventually gets treated as a real one and this alters your behavior.

For implanted false memories, again, the likelihood of creating one is a function of how plausible it is (Pezdek, Finger, & Hodge, 1997). In one study, students were asked to judge how well their own memories corresponded with those of their parents. During this, the researchers relayed a description of an event that was presumably described by the student's mother but that had never happened. This event was consistent with being raised either Jewish or Catholic. Jewish students were more likely to have a false memory for the Jewish event than the Catholic event, and vice versa, as shown in Figure 13.4. Thus, implanted false memories are more likely for plausible events. That said, it is possible to implant false memories of implausible events. For example, reading articles about demonic possession can make it seem more plausible, thereby leading to a false memory of witnessing demonic possession (Mazzoni, Loftus, & Kirsch, 2001).

In some unfortunate cases, people may experience implanted memories from overzealous and substandard therapists looking for repressed memories (Loftus, 1993). The suggestion that these "memories" have been repressed makes it more likely that a person will accept them as real. The normal scrutiny of the memory content and source does not seem to take place.

Increasing Implanted Memories

A technique that makes the creation of implanted false memories more likely is visualization, or imagination, which also increases confidence in the false memories. This is called **imagination inflation** (Garry & Polaschek, 2000; Mazzoni & Memon, 2003). Imagination makes memory traces richer and gives them more pseudoperceptual qualities, making them seem real. Suppose people heard about an event but did not see it. Now, if they also imagined the event, they are more likely to come to believe that it was seen (Henkel, Franklin, & Johnson, 2000). Imagination inflation has a greater influence when people take a first-person perspective (Libby, 2003) or with repeated imaginings (Thomas & Loftus, 2002). Both of these steps increase the perceptual “experience” in the memories, making them seem more real. Over time, if these imagined false memories are strong enough, people come to claim to consciously “remember” doing imagined events, even if they are odd activities, such as sitting on dice (Thomas & Loftus, 2002).

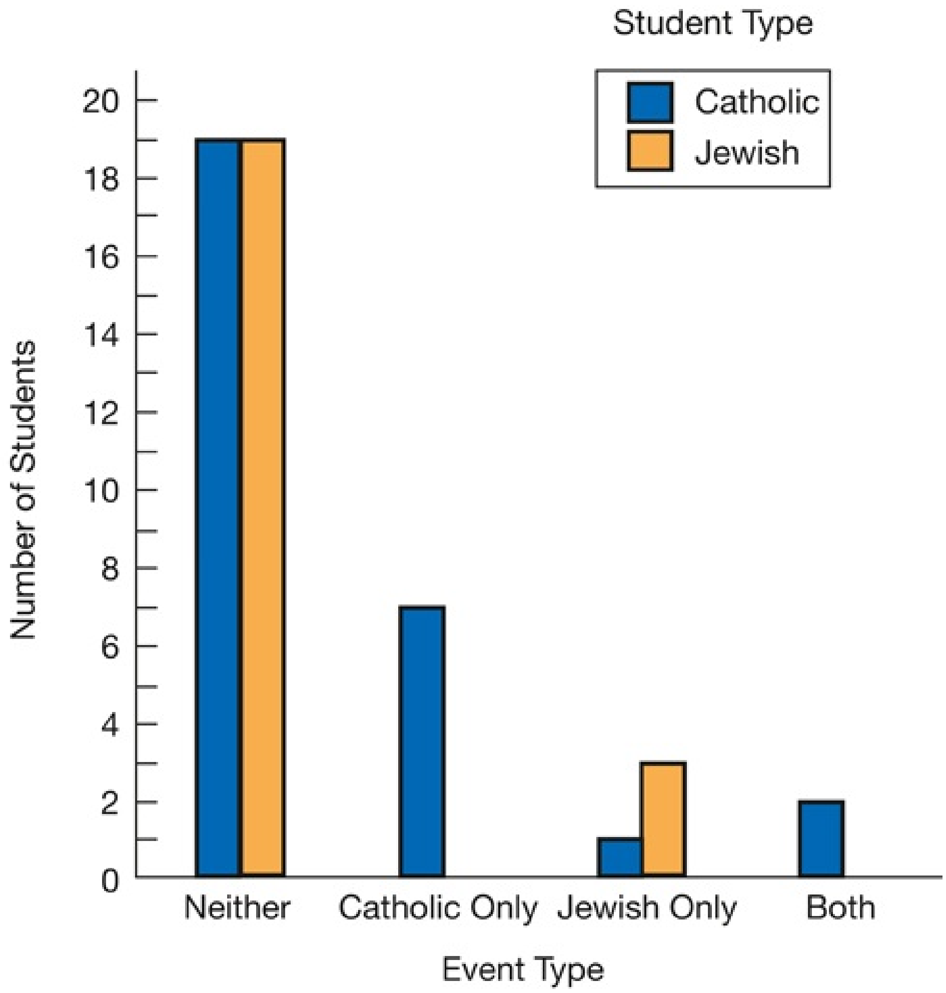

FIGURE 13.4 *False Memory Reports for Implanted Memories Consistent With a Catholic or Jewish Family Event*

Plotted from data reported in: Pezdek, K., Finger, K., & Hodge, D. (1997). Planting false childhood memories: The role of event plausibility. *Psychological Science*, *8*, 437–441

Given the power of imagination inflation, it is not surprising that actually viewing pictures can make false memories even more likely[2] (Garry & Gerrie, 2005). If people see photos of themselves at the age that an event was supposed to have occurred, they are more likely to create false memories (Lindsay, Hagan, Read, Wade, & Garry, 2004). Viewing old photos from a certain time period gives memory some concrete perceptual information to put into the false memories, along with any additional information that are triggered by seeing the pictures. These photos serve as raw source material to help build false memories. Similarly, if people see pictures of places under divided attention, when the encoding of source information is poorer, they may later misremember having been to those locations (Brown & Marsh, 2008). Although it seems unlikely, it is even possible for people to implant false memories into themselves. See the Study in Depth box overleaf to read about just how easy this is.

STUDY IN DEPTH

This box describes a study by Zaragoza, Payment, Ackil, Drivdahl, and Beck (2001). In this study, 98 students at Kent State University first watched an eight-minute excerpt from a live action Disney film about two brothers at camp. This portion of the study provided the event knowledge that would be manipulated later.

After viewing the film segment, the students were asked 12 experimental questions about the movie. Eight of these questions were about incidents or details that actually occurred in the film. The other four were about things that did not occur. For example, a question might be "the chair broke and Delaney fell on the floor. Where was Delaney bleeding?" In fact, the character did not bleed. All of the students were verbally asked by an experimenter and verbally spoke their response, which were recorded.

Thirty students were in a control group that was told to answer as best that they could but they were not forced to generate false information in response to questions if they did not know the answer, or if they did not believe that an event occurred in the film. The remaining 68 students were in the experimental group. They were told to answer the questions the best that they could. Moreover, if there was a question that did not correspond to an event that they remembered from the film, they were supposed to guess and generate an answer. Thus, this group knew that they were creating answers and not remembering that information from the film. In addition, for the experimental group, the researchers also manipulated the feedback that people received for their false memory guesses. For half of these, the students received confirmatory feedback (such as "yes, that's right"), and for the other half, they received neutral feedback (such as "okay").

A week later, the students returned to the lab where they were met by a new experimenter. This person told the students that the prior experimenter had made some mistakes and had asked questions about things that never happened in the film. Thus, if anything, the students were biased to be more conservative in their memory reports. During memory testing, people received 23 questions of the form "when you watched the video, did you see ____________?" Some of these were about answers that the student provided and some of these were about answers that another student provided. Some of the questions were about information that they generated false answers to and the rest were about things that actually happened in the film. Finally, four to six weeks later, the students who were asked to generate false answers were asked to return to the lab once more. This time they were asked to write down everything that they could remember from the film.

What is interesting is that students who knowingly confabulated answers during the first part of the study in the second part of the study accepted 32% of these answers as being the truth, compared to 8% in the control group (which provides an index of guessing). Moreover, if the experimenter had provided supportive, confirmatory feedback for a made-up response, then the rate of accepting self-implanted false memories was higher (38%) than if only neutral feedback had been given (26%). Finally, in the final recall task four to six weeks later, falsely generated knowledge was included in their recalls 27% of the time when the feedback was confirmatory and 13% of the time when the feedback was neutral. Thus, even minimal external support of self-implanted false memories boosts their creation tremendously.

Although people can falsely remember implanted information, there are some qualities that distinguish true from false memories. True memories are often richer in detail, are more emotional, are more likely to be consciously "recollected," and are more likely to be field memories. In contrast, false memories are more likely to be stereotypical events, to be "known," and to be observer memories (Frost, 2000; Heaps & Nash, 2001; Justice, Morrison, & Conway, 2013). That said, note that these are general tendencies and are not defining criteria that can be used to diagnose whether a given memory is real or not. True and false memories overlap each a great deal on all of these dimensions. These are only trends that characterize the false memories as a whole from true memories. It is like saying that men are taller than women. While this is true in general, there is a great deal of overlap between these two distributions. Just as you cannot make any firm judgments about the sex of people given their height, you cannot use such qualities of a memory to determine if it is true or false.

The Misinformation Effect

The storage of incorrect and false information in memory not only applies to knowledge about events that one personally experienced, as is the case with many of the false memories discussed in this chapter, but can also happen for general, semantic knowledge. The **misinformation effect** is the finding that people alter their memory reports to conform to incorrect information that was recently encountered and which contradicts their prior semantic knowledge.

As an example of the misinformation effect, when people read fictional stories about real people they tend to misremember some of the fictional information as being real. The fictional knowledge gets integrated with the real knowledge. Although people are aware that the story contained some fictional information, they also think that they knew some of the fictional information *before* reading the story (Marsh, Meade, & Roediger, 2003). What's more, if people are warned about this kind of memory distortion, even before they read, they still incorporate the inaccurate information into their semantic memories (Marsh & Fazio, 2006). As another example, although people know correct information ahead of time, such as the fact that the Pacific is the largest ocean, if they are exposed to misinformation, such as reading a fictional story that states that the Atlantic is the largest ocean, people will mistakenly use the misinformation to answer general knowledge questions soon after (Fazio, Barber, Rajaram, Ornstein, & Marsh, 2013).

The misinformation effect is more likely to emerge after a person has recently taken a test on the critical information (Chan & LaPaglia, 2013). This may be because the testing reactivates the requisite knowledge, which then is in a malleable state, prone to alternation, consistent with the process of reconsolidation (see Chapter 2). How well people can do this can vary and is related to the degree to which they are susceptible to DRM false memories (Zhu, Chen, Loftus, Lin, & Dong, 2013), suggesting that the same sort of memory retrieval processes that segregate true from false memories are operating in both cases.

False Memories: A Social Contagion

As with source monitoring, false memories can also be influenced by social factors. As a reminder, people are more willing to say that they "remember" events that were only imagined if other people claim that they saw them (Roediger, Meade, & Bergman, 2001; Reysen, 2007) or if they have a conversation with someone about a shared event (Rush & Clark, 2014). This influence of other people's memory reports on one's own memory is sometimes referred to in memory as a "social contagion." Just hearing other people relate events may cause us to remember them as if we experienced them.

That said, working with other people does not always lead to more false memories. For example, with the DRM paradigm, people working in actual groups recall presented words more accurately than people working in nominal groups or alone, however the rate of recalling false memories does not change (Maki, Weigold, & Arellano, 2008). Thus, the proportion of memories that are labeled false is decreasing, while the absolute rate of reporting false memories stays the same.

The social influence of implanted false memories is also affected by the people involved in a social setting. Specifically, false memories are more likely to occur in people who are more prone to dissociative experiences (e.g., driving and not remembering what happened the past few miles). Presumably these people have a harder time distinguishing between what was real and what was only imagined or was only plausible. Furthermore, false memories are more likely to occur when the person who provides the implanted information has a more extroverted personality. This influence is particularly strong when the person doing the remembering has a much more introverted personality (Porter, Birt, Yuille, & Lehman, 2000) or is the first person to recall something (Wright & Carlucci, 2011), suggesting some sort of primacy effect in terms of the preference for which information in memory is more accurate.

Emotional Connections

The influence of emotion on false memories is complicated. In the DRM paradigm, compared to emotionally neutral items, false memories are more likely if a set of words is emotionally negative but less likely if it is emotionally positive (Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008). The explanation is that negative emotional content encourages a person to rely more on gist-based processing, causing people to be more willing to remember something that is generally consistent with the actual information, producing a false memory. However, positive information encourages the use of more item-specific, verbatim memories, which decreases the likelihood of false memories.

In comparison to the emotional content itself, the emotional mood of the person can also influence the creation of false memories. In the DRM paradigm, relative to people who are in a neutral mood, false memories are more likely in people who are in a positive mood and less likely in people who are in a negative mood (Storbeck & Clore, 2005), although this may due to emotional intensity rather than negativity (Corson & Verrier, 2007; Kensinger & Schacter, 2006). Positive moods encourage relational processing, which would encourage the activation of a common associate concept, whereas negative moods encourage item-specific processing, which discourages the activation of what would become the false memory.

PHOTO 13.2 *Your emotions can influence the likelihood of forming false memories—although people are more likely to form false memories of negative information, people are more likely to form false memories when they are in a positive mood and may hear incorrect information from other people*

Source: monkeybusinessimages/iStock/Thinkstock

Hypnosis and Memory

If you are not familiar with the state of **hypnosis**, you should be aware that this is a real thing. It is an altered state of consciousness in which a person is more willing to accept and follow the suggestions of the hypnotist.[3] Also, people vary in the degree to which they can be hypnotized. Some people are not at all susceptible, whereas others are highly susceptible, to the point of being able to experience auditory, visual, or tactile illusions as suggested by the hypnotist.

While there are many interesting topics that can be explored with hypnosis, the issue at hand is how hypnosis influences memory. Does hypnosis make memory better, make it worse, or have no appreciable effect? At first blush, it seems that hypnosis has a beneficial effect on memory. If you put people under hypnosis and ask them to recall things, they report more than if they are not under hypnosis. There are also some salient anecdotal reports about the effectiveness of hypnosis on memory.

One well-known report involves the Chowchilla kidnapping (as reported by

Smith, 1983). In 1976, members of the Symbionese Liberation Army (a militant radical sect) kidnapped, at gunpoint, a bus full of schoolchildren and their bus driver. They were herded into a couple of vans and taken to an old rock quarry. At the quarry the students and bus driver were placed into a buried chamber. Eventually the bus driver and students were able to dig themselves out and go to the police. When questioned, the bus driver said that he had tried to memorize the license plates of the vans as they were being loaded onto them. However, because he was so agitated while being held at gunpoint, he was unable to recall the plate numbers. At this point, a decision was made to hypnotize him in the hope that this would help him remember. While under hypnosis, the bus driver called out two license plate numbers. One of these, except for one digit, turned out to be the plate number for one of the vans. This information eventually led to the arrest and conviction of the kidnappers. With reports such as this, it can be seen why some people would view hypnosis as a memory technique with great practical potential.

Perhaps more familiar are cases where people are hypnotized under therapeutic situations. The movie *Communion* provides a striking example of this when a man is hypnotized and recalls his abduction by aliens. More down-to-earth and common examples are cases where people are hypnotized in therapeutic sessions to remember aspects of their past that they may have forgotten because they had been traumatized by the event. Often these approaches to using hypnosis take the view that memory is like a videotape that accurately records events that occur and that can be played back with a high level of accuracy if the proper technique is used. This is incorrect.

There is no doubt that people report more memories under hypnosis, but there are serious problems. For one thing, there is a larger risk that the memories people report are inaccurate (Scoboria, Mazzoni, Kirsch, & Milling, 2002; Smith, 1983). The new accurate information that is reported under hypnosis is no different from the hypermnesia that one would normally see with repeated recall (see Chapter 3). As a reminder, when people are asked to remember something over and over again they can often remember things in later attempts that they had forgotten previously. This was demonstrated in a study by Dinges et al. (1992), in which people were given 40 line drawings to look at and memorize. People were then asked repeatedly to report what they had seen either when they were hypnotized or not. A forced recall test (see Chapter 3) was used, in which the people had to recall 40 things. Thus, hypnotized and unhypnotized people reported the same overall amount of information. What was found was that there was no difference in how much was recalled when people were either hypnotized or not. Consistent hypermnesia was observed in all cases. Thus, hypnosis adds little to the ability to remember more than what is normally seen. The only possible benefit of hypnosis could be to calm a person who is highly anxious. However, this can also be accomplished by other methods and without the risk of the potential recall of false memories.

Stop and Review

False memories can be implanted from outside sources, including self-implantation. The likelihood of a false memory being implanted is increased the more retrieval attempts there are and by engaging in mental imagery and imagination of the implanted events. Moreover, implanted false memories can be made for otherwise well-known semantic knowledge of the world (the misinformation effect). The formation of false memories is also affected by our emotions. We are more likely to form false memories of negative emotional content but are more likely to form false memories when we are in a positive mood, perhaps because in those moments we are less rigorous in our thinking. The false memory implanting unintentionally occurs as part of our interactions with other people when there is a sharing of experiences, particularly when the other people who are more extroverted and trusted. False memories can also arise through hypnosis and they are often remembered at a high level of confidence. All of that said, while we can be easily misled in some circumstances, our grip on reality is fairly firm and we tend not to create false memories wildly.

FALSE MEMORIES THROUGH NORMAL MEMORY USE

Every time we use our memories we change them in some way. Different things that we do with the information alter our memories' content. In this section we look at examples of normal ways of using memory that can lead to false memories. These are verbal overshadowing, the revelation effect, and the blending of memories.

Verbal Overshadowing

When we talk about things we've seen, our memories can be changed by the act of verbalization. This is **verbal overshadowing**. When we describe an event, we create a verbal memory of our description. Because verbal information differs from visual information, our memory for what we said alters our memory for what we saw. This is consistent with fuzzy trace views, which suggest that memory is a mixture of various traces. Overall, somehow our more recent verbal memories overshadow our older visual memories.

As an example of this, in a study by Schooler and Engstler-Schooler (1990), students at the University of Washington watched a videotape of a bank robbery. Afterward, some people were asked to spend five minutes writing a verbal description of the robber's face. Everyone was then shown a set of eight pictures of similar faces and asked to pick out which one was the robber, if his picture was there at all. (In fact, the face of the robber was present.) It was found that students who produced a verbal description of the robber's face correctly picked it out less often than students who did not write the description. Thus, memory was worsened by talking about the experience. Verbal overshadowing can even occur when naming pictures of simple objects (e.g., saying "chair" to a picture of a chair) (Lupyan, 2008). It should be noted that verbal overshadowing does not occur if people only read a description—only when they actually generated a description does it occur (Dodson, Johnson, & Schooler, 1997).

The verbal overshadowing of something like the face of a person involved in an event can occur even when it is not the face that is described. In a study by Dodson et al. (1997), verbal overshadowing was present even when people wrote descriptions of another face. Moreover, Westerman and Larsen (1997) found verbal overshadowing for people who wrote descriptions of a car that was in a videotaped scene. Even under these conditions, memory for the face became more difficult. Thus, verbal overshadowing can influence the types of information that are sought during retrieval. There is a shift from visual to verbal information. Alternatively, it has been suggested that verbalizing may alter the recognition process and make people more conservative because the verbal overshadowing effect is less likely to occur when people are forced to make a choice between several alternatives (Clare & Lewandowsky, 2004). Either way, talking about things can sometimes make memory worse. Finally, there is some evidence that verbalization may act as a form of retrieval practice in that details that are not talked about will be forgotten, even for emotionally intense events, such as hearing of the September 11, 2001, terrorist attacks (Coman, Manier, & Hirst, 2009).

While verbal overshadowing occurs, it is not always the case that providing a verbal description will make memory worse. In some cases, verbal facilitation can occur (e.g., Brown & Lloyd-Jones, 2005, 2006; Lyle & Johnson, 2004). For example, if people are presented with a series of different faces and provide a description of each one as it occurs (in a control condition, no description is provided), they adopt strategies of encoding faces to memory that can take advantage of these verbal descriptions.

Revelation Effect

When we interact with the world, sometimes information is revealed slowly. At such times we may be trying to figure out what we are dealing with. As a consequence of this revelation process, people are more likely to recognize information as old, for both old and new information. This is the **revelation effect** (Luo, 1993; Peynircioglu & Tekcan, 1993; Watkins & Peynircioglu, 1990) and it can also occur when people make frequency judgments (how often something occurred) in addition to recognition judgments (Bornstein & Neely, 2001). There are several ways that the revelation effect is studied. For example, a word might be revealed one letter at a time until the person can make a recognition judgment (e.g., M _ _ _ _ _, M _ _ O _ _, M _ _ O _ Y, etc.). The revelation effect occurs only when people think they are remembering a prior event. It does not occur if people either know that no such episode occurred or if they engage in semantic memory retrieval (Frigo, Reas, & LeCompte, 1999; Watkins & Peynircioğlu, 1990).

The revelation effect appears because people are using memory familiarity (Cameron & Hockley, 2000; LeCompte, 1995; Westerman & Greene, 1996; but see Hicks & Marsh, 1998, and Niewiadomski & Hockley, 2001). As people go through the revelation process, the information feels more familiar so they are more willing to claim it was seen before. This occurs even when people have not heard something before but were subjected to subliminal suggestions that they had (Frigo et al., 1999). ERP recordings of the frontal lobes show that there is greater cortical activity for information that was revealed, which is consistent with the idea that people are relying on memory familiarity (Azimian-Faridani & Wilding, 2004).

Consistent with this familiarity idea, the revelation effect is more likely when people are less able to consciously recollect the circumstances in which information was learned and need to rely on feelings of familiarity. So, having a longer delay between the original presentation and the memory test or presenting the information faster makes it harder for people to encode it in a way that makes conscious recollection possible (Landau, 2001). This feeling of familiarity may even come in the form of general activation by a presumably unrelated prior task, rather than revelation itself, such as performing a working memory span task prior to recognition (Westerman & Greene, 1998) or by solving a problem such as an anagram (Dougal & Schooler, 2007). However, when retrieval emphasizes conscious recollection, the revelation effect may not be observed (Westerman, 2000).

What is striking about the revelation effect is that it not only applies to simple items, like words, but also to complex events (Bernstein, Godfrey, Davidson, & Loftus, 2004; Bernstein, Rudd, Erdfelder, Godfrey, & Loftus, 2009; Bernstein, Whittlesea, & Loftus, 2002). If people go through a process of trying to uncover their memories, this very uncovering process can increase the likelihood that a person will falsely claim that a memory is real. Thus, efforts at recovering previously hidden memories by engaging in imagination can lead a person to believe in false memories.

The revelation effect is similar to other phenomena, including the mere exposure effect (Chapter 6) and the false fame effect, in that memory is altered by prior encounters. More false memory reports occur if people are exposed to a brief preview of something, such as a word, face, or scene. This preview makes something seem more familiar and people are more likely to report that they had encountered it earlier (other than the preview) (Brown & Marsh, 2009; Jacoby & Whitehouse, 1989; Titchener, 1928). This may partially explain a déjà vu experience. Sometimes people get an initial glace of something and then, later, when they look at it more carefully, it seems oddly familiar.

Memory Blending

A final way that false memories can be created is when information from different memory traces is blended during the process of retrieval. As a reminder, some aspects of memory retrieval are reproductive. That is, information that was encountered before is directly retrieved from memory in more or less the same form that it was originally encountered and encoded. For example, when you remember the name of the street you grew up on, you are reproducing this information. That said, much of our memory is reconstructive. That is, we have bits and pieces stored in memory, and we reconstruct those memories from other knowledge that we have. This might be done using schemas and scripts (see Chapter 9). As a result of these reconstructive processes, elements from different events may be blended together during retrieval to form a composite memory of an event that never actually happened (Devitt, Monk-Fromont, Schacter, & Addis, 2016). This is more likely to happen when the original events are similar in some way. For example, if you made multiple trips to visit the Smithsonian museums in Washington, DC, you might combine events from different trips into a single composite memory.

Improving Your Memory

One of the primary concerns about memory for many people is that their memories be accurate. The very term “false” in false memory has a negative connotation. So, what can be done to make our memories more accurate? As you’ve seen, there are a number of things that can cause memory and reality to become disconnected. In terms of source monitoring, remember that this is a problem solving process. Cognition is putting many different pieces of information together to figure out what the source of a memory may be. At the time of the event, if remembering the source is going to be important, do what you can to make it salient in your memory. For example, if you heard a secret from Elise, try to form a mental image of Elise carrying a briefcase full of secrets. This will make the knowledge more memorable so that you can bring that fact to mind when needed. After the fact, you’ll just need to be careful and work with whatever knowledge you have. In general, be aware of circumstances when source memory can fail you so that you don’t put yourself in an embarrassing situation.

In terms of the false memories that are generated through memory processes such as those found in the DRM and integration paradigms, keep in mind that this involves a cognitive process that is normally quite valued, namely making inferences. As was noted in Chapter 8, some of the sins of forgetting exist because they are often actually virtues. Just be aware that sometimes you may be mistaken and that other people may be remembering accurately. In terms of avoiding the implanting of false memories, if some event is important to remember, first, try to avoid talking to other people when it is reasonable to do so. This may preserve the accurate portions of the memory for the event. Alternatively, allowing yourself to imagine events, causing imagination inflation, leading people to say that events might have happened when they did not. Finally, talking about events can sometimes cause memories to be distorted and lost, as with verbal overshadowing. This is why some people don’t like to talk about movies or television shows just after they watched them. Giving them some time will allow them to be consolidated and not lost through verbal overshadowing.

This kind of memory blending may also happen when you watch other people doing something (Lindner, Echterhoff, Davidson, & Brand, 2010) or when you engage in counterfactual thinking and imagine how the world may have been different (what if you actually had picked up that litter on the way to school and thrown it away instead of just letting it sit there?). Again, people may blend imagined and actual events to form a new memory (Gerlach, Dornblaser, & Schacter, 2013).

There are several examples of memory blending that have been discussed in other sections of this book. For instance, the integrative false memories discussed earlier in this chapter are a form of memory blending. The use of schemas and scripts, as described in Chapter 9, to fill in the gaps in our memories is another. Also, formal memory models, such as MINERVA 2, described in Chapter 10, also incorporate the idea that memory retrieval always involves a blending of memories.

CONFABULATION

Up to now we have been discussing disconnections between memory and reality as they might occur in normal individuals. At this point it can be noted that certain kinds of brain damage result in patients reporting things that are clearly not based on reality but are false memories that they generate. These are false memories and not lies because the patient believes them to be true at the time that they are reported. There is no intention to deceive. This generation of false memories as a result of brain injury is called **confabulation**. For example, after his stroke, my grandfather would tell stories of things my father did when he was younger, even though my father never did those things. Instead, those were events that my grandfather had seen in a television show.

Confabulation is a symptom that may occur with damage to the frontal lobes. This can be thought of as damage to the central executive of working memory. The patient reports what he or she believes to be the truth. Even when the confabulations are very bizarre the person is unaware of any memory problems. For example, a man might claim to have been married for only three years but have two full-grown children as a result of that marriage. Another feature of confabulation is that a person might see some object in the environment which could trigger a confabulatory report. For example, a patient might see a picture in a room of a tropical beach. This could trigger a report of the time the patient went on a trip to Hawaii, even though that person had never actually been there.

What is happening with confabulation is that a person is not able to effectively monitor memory and evaluate the results of their own retrieval. Thus, incorrect information is reported as if it were true. Confabulatory reports are often confined to episodic memory, with a strong metamemory sense of remembering. Semantic memory is largely unaffected (Barba, 1993). So, people are unconsciously inventing information about their lives while their general understanding of how the world is structured and operates is relatively intact.

Stop and Review

False memories can be created through what would seem to be the normal use of memory. For example, describing a witnessed event can lead to memory distortions, even when the part of the event being described is not what is tested later. Also, the gradual recovery or revelation of information during a memory search can create false memories. The build-up of partial memories leads to greater feelings of familiarity. False memories can also be crated through a blending of related memories in a (false) composite memory. Finally, some kinds of brain damage, particularly damage associated with the frontal lobes, can cause affected people to have trouble regulating their memory processes, causing them to confabulate memories of events that never actually happened.

PUTTING IT ALL TOGETHER

Typically, when you remember, you remember things that happened. However, sometimes you remember things that did not. False memories can come about through how the material was encoded into memory, how it was stored, and how it was later retrieved. During encoding, you may use your semantic world knowledge to make inferences and these inferences then get inappropriately stored as memories of actual events. This may be what is happening in the DRM word list paradigm. This is more likely for negative information, which may encourage you to form inferences to understand negative content. Alternatively, your false memories may be implanted by others (or even self-implanted). This is more likely when retrieval attempts are repeated, you engage in mental imagery, and are encouraged by other people. This last situation would be the case with hypnosis. One thing that happens with hypnosis and other circumstances is that knowledge may come to consciousness slowly. This gradual revelation may lead you to treat false memories as real. This slower revelation leads to greater feelings of familiarity.

During memory storage, false memories may be generated by combining information from experiences that you encountered separately. If they refer to a common state of affairs, they are integrated into a single memory. These blended memories may not be distinguished from the individual memories that were used to construct them. Alternatively, talking about an event can produce verbal memories that then overshadow an original memory, causing a distortion in what is remembered. This overshadowing can even occur for otherwise well-known world knowledge, as with the misinformation effect.

During retrieval, a memory can be in error if you lose the source of that information. This can be a problem in external or internal source monitoring or reality monitoring. When these mistakes occur, you may use that knowledge in an inappropriate manner, such as with cryptomnesia, the false fame effect, and the sleeper effect. This is more likely to happen when you are in a good mood and are not being careful in how you retrieve and appraise information from memory. With some kinds of brain damage, you might not be able to regulate the flow and evaluation of information during retrieval. This can cause you to confabulate and produce false memories that you believe, even if they are bizarre.

STUDY QUESTIONS

1. What is source monitoring? How is it different from destination memory?
2. What are the different types of information that memory uses to perform source monitoring?
3. What are the different types of source monitoring?
4. Generally speaking, what happens when a source monitoring error occurs? More specifically, what are some of the ways that source monitoring errors produce problems?
5. What is source monitoring and how can this help memory retrieval?
6. What are cryptomnesia, the false fame effect, the sleeper effect, and the wishful thinking bias? How are each of these related to the process of source monitoring?
7. How can false memories be created by hearing related sets of information as in the DRM paradigm?
8. How might false memories be created through an integration process?
9. How are false memories implanted? What can be done to influence the probability that a false memory will be created?
10. How might semantic memory be distorted in the misinformation effect?
11. In what circumstances might false memories become a social contagion?
12. How is the creation of false memories influenced by emotions?

13. What is the best way to describe the effect of hypnosis on attempts to remember?
14. What is the influence of providing a verbal description of a witnessed event on memory?
15. Does slowly revealing information to people make memory more or less accurate? Why?
16. How can memory be disconnected from reality through processes that result in memory blending?
17. What is confabulation and how does it arise?

KEY TERMS

- affective information
- cognitive operations
- confabulation
- contextual information
- cryptomnesia
- destination memory
- DRM paradigm
- external source monitoring
- false fame effect
- false memories
- hypnosis
- imagination inflation
- internal source monitoring
- misinformation effect
- perceptual detail
- reality monitoring
- revelation effect
- semantic detail
- sleeper effect
- source monitoring
- verbal overshadowing
- wishful thinking bias

EXPLORE MORE

Here are some additional readings that can provide better insight into issues of memory and reality.

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NOTES

1. A related phenomenon is **destination memory**, our ability to remember to whom we have told things (Gopie & MacLeod, 2009).
2. Although narratives have an even bigger influence (Garry & Wade, 2005).
3. It may be that it is the suggestions, not the hypnotic state itself, that is relevant (Kirsch, Mazzoni, & Montgomery, 2007).

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CHAPTER 14

Memory and the Law

Memory has practical and important applications. Currently, for most of you, one of the more important applications for memory is for the learning of a large set of facts that can be written on an exam or used to develop a term paper. Hopefully, some of what you have learned here can be applied to make those efforts more successful. However, there are many other applications outside of the classroom. One of the more salient of these is how memory works, and how forgetting occurs, in the legal arena. There are many situations in which arriving at a just and legal outcome involves people using their memories effectively. If memory is more accurate, then police, judges, and juries can come to more appropriate conclusions. However, as we have seen, memory reports may be inaccurate, even though people are doing the best that they can. In a legal setting, such memory errors can lead to miscarriages of justice, with guilty individuals not being held accountable and remaining at large or innocent people being punished for things they did not do.

This chapter looks at five ways that memory can influence the unfolding of legal matters. The first is the accuracy of eyewitness memory. That is, how well does an eyewitness remember the events that they saw to the degree that they can give accurate reports to investigators? The second is the confidence eyewitnesses have in their memories. The third is the development of a cognitive interview used to gather information in a way to get the most out of a person's memory. The fourth is the use of memory to identify a perpetrator from a lineup. And, for the fifth, we consider how memory processes influence the effectiveness of juries.

EYEWITNESS TESTIMONY

When an automobile accident occurs, or a crime is committed, one important source of evidence is **eyewitness testimony**. Eyewitnesses can provide information that cannot be obtained any other way. Moreover, if it is a serious enough case to warrant a jury trial, eyewitnesses can provide some of the most convincing evidence to jurors. Thus, the accuracy, stability, and scope of eyewitnesses' memories are critically important. It is vital to understand how accurate such accounts are, even in the absence of any desire to mislead on the part of a witness.

We approach the accuracy of eyewitness reports by looking at some things that can affect eyewitness memory. For instance, how can the wording of a question influence memory? What influence does misleading information have on memory and why? How does the witness's emotional state at the time of the event affect later memory? Are there other aspects of the event that influence later memory?

Wording Effects

To get information from a witness, questions must be asked. How questions are worded can influence what is remembered. People reconstruct their memories of an event based on the questions they are asked, which serve as memory cues. Take the example of an automobile accident involving two cars.[1] In some studies, people watched a film of a car accident. Note that in the actual film there was no broken glass. Yet, as part of a series of questions, people were asked if they had seen any broken glass. In this case, the critical question included the verbs "smashed" or "hit" to describe the accident. What was found was that the more severe the verb, the more likely people claimed to have seen broken glass (Loftus & Palmer, 1974). People reported broken glass 16% of the time when they heard "smashed" in the question but only 7% of the time when they heard "hit." People in a control condition said "yes" to the broken glass question only 6% of the time. So, the wording of a question can influence eyewitness memory.

This influence of wording even occurs for what might seem to be very subtle differences, such as whether a question contained the articles "a" or "the." In one study (Loftus & Zanni, 1975), people saw a car accident film. They then wrote a summary of what they saw and answered some questions. One question was either "did you see a broken headlight?" or "did you see *the* broken headlight?" The difference between the articles "a" and "the" is important because "a" doesn't presuppose the existence of a broken headlight, whereas "the" does. Half the time the questioned item was present in the film and half the time it was not. When the item was not in the film (e.g., no broken headlight), people claimed they saw the (nonexistent) item 7% of the time when "a" was used but 18% of the time when "the" was used. The error rate is more than twice as large following a change in a seemingly small function word.

Misleading Post-Event Information

As you may have guessed, because it is so easy to alter memory reports based on the wording of a question, it is also alarmingly easy to alter memory by giving misleading information afterward, whether intentionally or not. This is called **misleading postevent information**. This misinformation enters memory and people have difficulty distinguishing it from accurate memories. These memory distortions come from hearing other people describe the event, with memory reports being distorted in the direction of what a person has heard other people say (Wright, Memon, Skagerberg, & Gabbert, 2009). The effect of misleading postevent information can be exacerbated by the presence of nonverbal information that supports the incorrect information, such as gestures (Gurney, Pine, & Wiseman, 2013). We first look at how to assess the influence of misleading postevent information and then consider some theories that try to explain how this happens.

A standard approach for assessing the influence of misleading postevent information on memory was first used by Loftus, Miller, and Burns (1978). For this paradigm, first, people watch an accident or crime on video. For example, people might see an accident in which a driver goes past a yield sign. Then, people are asked questions about the video. A critical question refers to an object that was in the scene, such as “did another car pass the red convertible when it was stopped at the yield sign?” Because the sign mentioned in the question is in the video, this is the *consistent* condition. In other cases, this question refers to an object that was not in the scene, such as “did another car pass the red convertible when it was stopped at the stop sign?” Because no stop sign was in the video, this is the *misleading* condition. Finally, in a third, *neutral*, control condition, the question was a neutral reference to the critical object, such as “did another car pass the red convertible when it was stopped at the traffic sign?”

After viewing the event and answering a critical question (among others), people make a decision about what they saw—such as choosing between pictures or verbal descriptions. For example, people might make a choice about whether the car had stopped at a stop sign or a yield sign. Although memory is better in the consistent condition (relative to the neutral condition), performance is worse in the misleading condition. The results of one study are shown in Figure 14.1. This shows that people incorporated the misleading information into their memory of the eyewitnessed event.

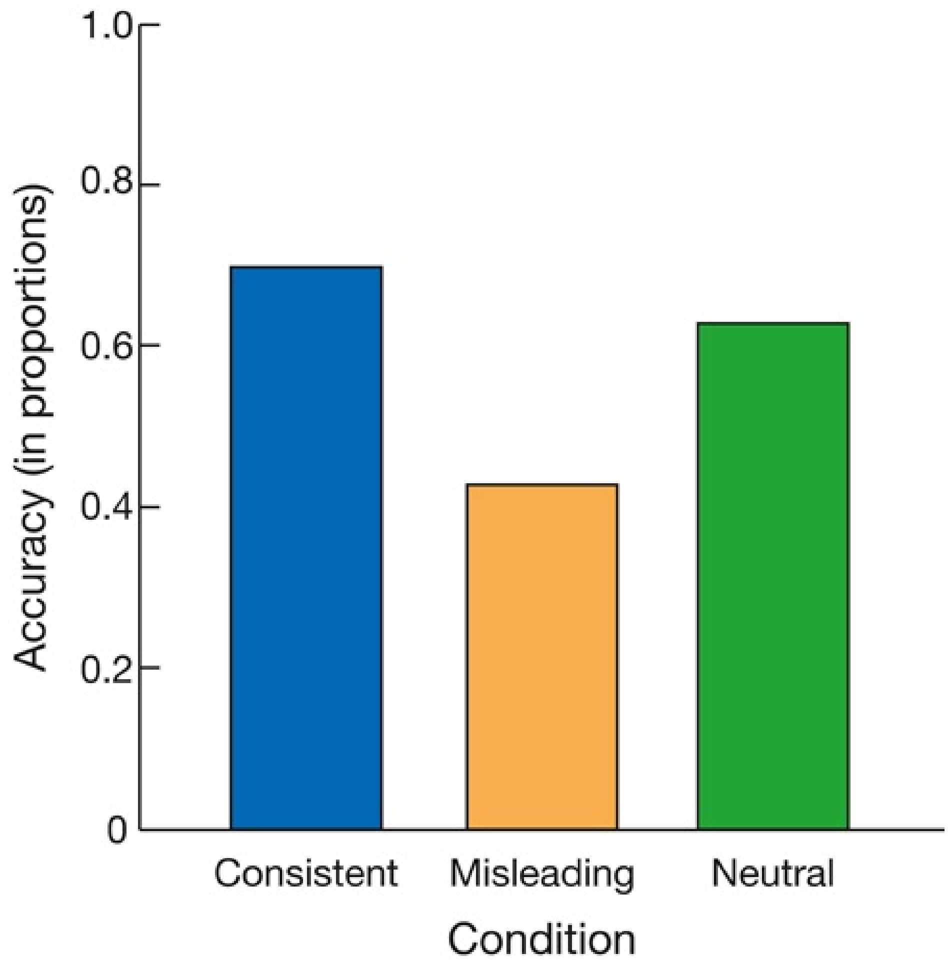

FIGURE 14.1 *Proportion Correct for Selecting the Correct Item after Consistent, Misleading, or Neutral Information*

Derived from data reported in: Loftus, E. F., Miller, D. G., & Burns, H. J. (1978). Semantic integration of verbal information into a visual memory. *Journal of Experimental Psychology: Human Learning & Memory*, *4*, 19–31

This misleading postevent information effect is fairly stable and occurs in a variety of situations. It is more pronounced the greater the delay between witnessing the event and the time the misleading information is encountered (Loftus et al., 1978). It also occurs when the misleading information is presented prior to witnessing the event (Eakin, Schreiber, & Sergent-Marshall, 2003). People can even mislead themselves. Witnesses who provide false information (i.e., deliberately lying about what they saw) after witnessing an event have a poorer memory when they later try to remember accurately. They retrieve less true information and are more likely to have their lies intrude on their attempts to remember (Pickel, 2004). In their minds, their lies have become truths.

TRY IT OUT

One of the salient research paradigms in research on eyewitness memory is the misleading postevent information paradigm. In this paradigm, people witness an event, and then afterward, they are exposed to information that is inconsistent with what was actually observed. To assess this yourself, first, get a video of some extended event. This video can be one that you make or one that you find on the internet. The video can be an automobile accident or a crime but it does not have to be. All it needs to be is a video that shows something happening. It doesn't even need to be live action. It could be animated. This video should a few minutes long and contain enough elements that would allow you to later mislead your viewers.

From this video identify some element that you will mislead some people about. Come up with an alternative that would be plausible in that situation but which was not actually seen. For example, a road sign could be a stop sign in the video and you could choose a yield sign as the misleading item. Alternatively, if the video is of a crime, the criminal might move a calculator on a desk in the video and you could use a cell phone as your misleading item. Choose whatever makes sense for the event that you've picked.

For this study you'll need at least three groups with 20 or more people in each group. These groups will be (1) control, (2) repeated, and (3) misled. At the beginning of the study, have all three groups watch the same video. Then, after the video, give participants a short distractor task in which they do something unrelated to the task at hand for five minutes. For example, you could have them solve Sudoku puzzles.

After the distractor period, give the participants with a series of questions about the event they watched. About 12 to 20 questions should be sufficient. All but one of these questions should be about things that actually happened, such as "was the car following a truck when it passed the drugstore?" Overall, half of the questions should elicit a "yes" answer and half a "no" answer. Importantly, among the filler questions, you should have a critical question. For the neutral group, the question should refer to the critical item in general terms, such as "did the car turn right at the traffic sign?" For the consistent group, the question should refer to the actually seen critical item, such as "did the car turn right at the stop sign?" Finally, for the misled group, the question should refer to the misleading item, such as "did the car turn right at the yield sign?" This question should be worded so that the assumption in the question is that the misleading item is true.

After the question period, there should be another distractor period similar to the earlier one. After that distractor period, you should have a final forced choice recognition test. This test should consist of about a dozen items. For each item, the question should ask about some detail of the video and there should be three options to choose from. For example, a question might be "what was the car following when it passed the drugstore: (a) truck, (b) SUV, (c) motorcycle?" The critical item in this test will assess whether people will distort their memories in favor of the misleading postevent information. This critical question should contain answers that are the original item, the misleading item, and a new item. For example, the critical question could be "at what sort of traffic sign did the car turn right: (a) stop sign, (b) yield sign, (c) no parking sign?"

After your participants are done, collect their responses. Total up the number of correct, misled, and other answers for the critical item and see how the rates of these responses varied across the three groups. What you should find is that the rate of reporting the misled items should be greater for the misled group than the other two groups. For interesting variants, you can look at different types of videos, different ways of presenting the misleading information, different retention intervals, or anything else that you think could influence the outcome.

A number of explanations have been given for why eyewitness memory reports are altered by misleading postevent information. These theories vary in terms of the fate of the original information and how the misleading information comes to dominate later responses. The three that are covered here are memory replacement theory, memory coexistence theory, and source monitoring theory. Each of these has some support and it is likely that the misleading postevent information effect is driven by multiple causes (Belli, 1989; Loftus & Hoffman, 1989).

For **memory replacement theory** (Loftus, 1979), misleading information replaces or overwrites the original memory, which is permanently lost or altered. This can be seen when people are given three alternatives on the memory test, in which one was the original item (e.g., a yield sign), one was the misleading item (e.g., a stop sign) and a third was a new item (e.g., a no parking sign). After the initial response, people selected their best second guess. If people initially selected the misleading item, the probability of selecting the correct item as a second guess is at chance. If the original memory were still present, then performance should have been higher. These results are consistent with the idea that the original information is absent from memory.

A second view, **blocking theory**, is that the original and misleading information coexists in memory but the original information is being blocked by the newer information. Because the misleading information is more recent, it has a stronger activation level in memory. As such, it obscures the original memory, making it difficult for a witness to be accurate. It has been shown that if people are asked to recall an event prior to being exposed to misinformation they are more likely to accept the misinformation (Chan, Thomas, & Bulevich, 2009). Recalling the event may make it easier to bind and integrate the misinformation into memory, blocking access to the original memory. This is similar to the processes of reconsolidation in which memories are altered.

It may even be the case that the original memory is inhibited, similar to what happens in the retrieval practice paradigm (MacLeod & Saunders, 2005). A study by Berkerian and Bowers (1983) showed that, if the context is adequately reinstated at the time the questions are asked, then the effect of misleading postevent information is reduced or eliminated. This was done by having the questions match the order in which the event originally unfolded rather than in a random order. In another study, by Christiaansen and Ochalek (1983), people were warned before the memory test that some of the questions contained misleading information. With this warning, people were able to disregard some of the information and perform more like people who were not misled. Thus, they were able to remove the memory traces containing the misleading information, which were blocking access to the original memory, and focus only on those traces from the original event. Finally, even when there appears to be no memory for the original event on a direct memory test, like recognition, there is evidence that the information is still present when an indirect memory test is used, such as lexical decision (Dodson & Reisberg, 1991).

A third view, **source monitoring theory**, suggests that there may be a source monitoring problem (see Chapter 13) causing the misleading postevent information effect. Witnesses who encounter misleading information generally remember where it came from (Zaragoza & Koshmider, 1989). However, errors do occur. These source monitoring errors are more likely for people who are more dissociative thinkers and can more readily disengage from external reality (they also show a lower correspondence between their accuracy and their confidence) (Cann & Katz, 2005).

It should also be noted that when people are creating such incorrect descriptions themselves this makes their memories even worse (Lane & Zaragoza, 2007), particularly if such self-generated false reports are created to help explain why something may have happened (Chrobak & Zaragoza, 2013).

This can even extend to people coming to accept as real the memories they generated as part of the process of producing a false confession (Porter & Baker, 2015; Shaw & Porter, 2015). This heightened belief in self-implanted memories is because self-generated inaccuracies bring the misinformation, generation, and verbal overshadowing effects together to work against accurate source monitoring. Reflective thinking makes the aspects of memory that distinguish source more obscure, leading to an increase in source monitoring errors. The more thematically similar misleading information is to the witnessed event, the more likely it is that errors are made.

Just because a person encounters misleading information does not mean that memory is altered. It depends on the trustworthiness of the source. For example, misleading information about an accident is more likely to have an effect if people think it came from a bystander than if it came from a driver involved in the wreck, in which case people are more likely to disregard the misinformation (Dodd & Bradshaw, 1980). In an interesting twist, Assefi and Garry (2003) found that people were more susceptible to misinformation if they thought they had recently consumed alcohol (even though they hadn't because the experimenters gave them drinks that only tasted like alcohol but weren't), as seen in Figure 14.2. Thus, even implicit social demands can influence eyewitness memory. What was even more disconcerting was that people who *thought* they had consumed alcohol not only made more errors but were also more confident in their answers.

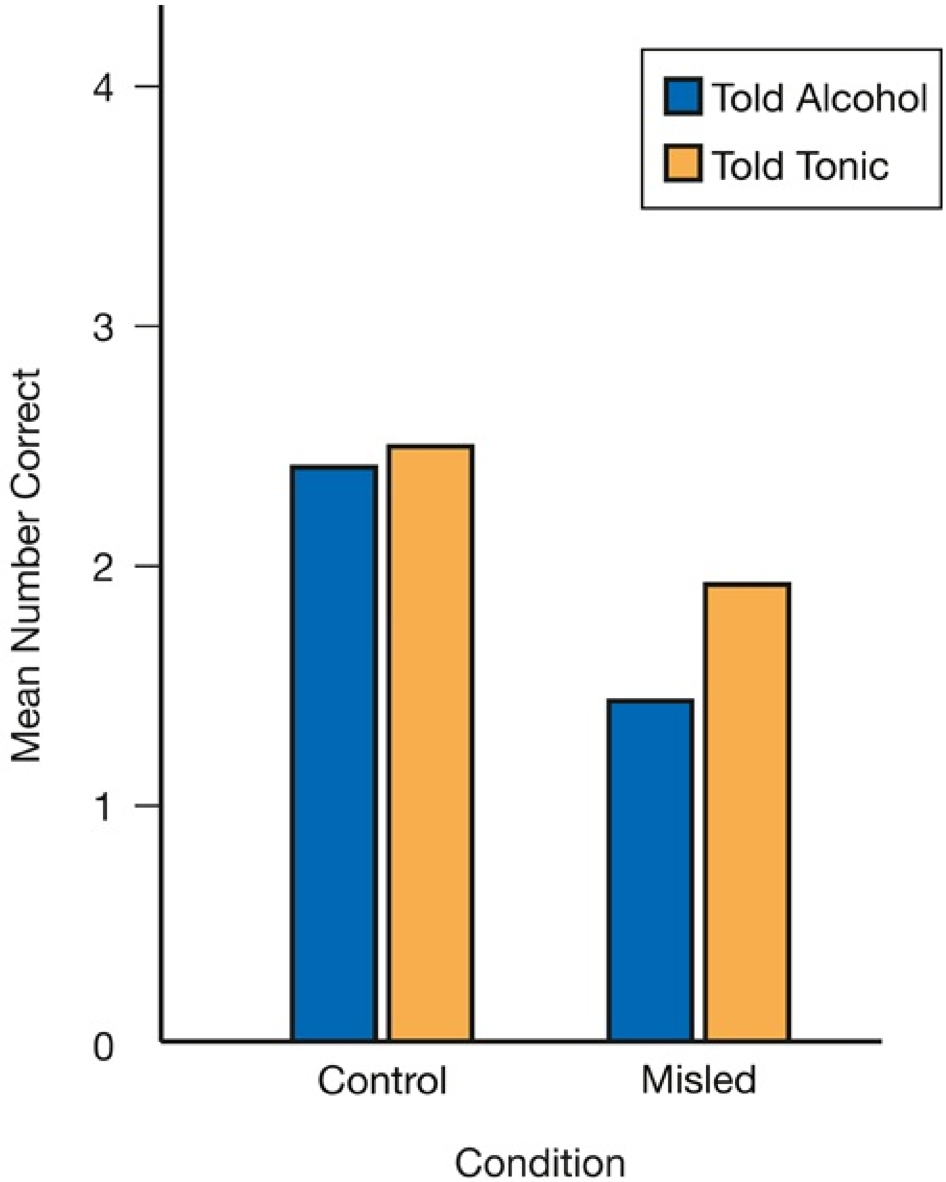

FIGURE 14.2 *Influence of Perceived Alcohol Consumption on Memory Performance*

Adapted from: Assefi, S. L., & Garry, M. (2003). Absolut memory distortions: Alcohol placebos influence the misinformation effect. *Psychological Science*, *14*, 77–80

Arousal Influences

Events involving eyewitnesses are often not standard and mundane. Instead, they are emotion-arousing situations, as when someone witnesses a violent car accident or is a victim of a serious crime. How do intense emotions affect eyewitness memory? Do emotions make it better? Do they make it worse? Well, the picture is somewhat complicated, although there is no doubt that memory is influenced by emotion (see Deffenbacher, Bornstein, Penrod, & McGorty, 2004 for a meta-analysis) or arousal from physical exertion (Hope, Lewinski, Dixon, Blocksidge, & Gabbert, 2012). This relationship is outlined by Christianson (1992).

One early view was that emotion and memory followed the **Yerkes–Dodson law** (Yerkes & Dodson, 1908). According to this view, arousal is a continuum, with memory performance being an inverted U-shaped function, as shown in Figure 14.3. At low levels of arousal, people do not encode information into memory very well. This is like trying to study when you are tired. As arousal increases, performance increases as well, up to a point. There is a certain level where memory is maximized. Beyond that point, people are overaroused and memory worsens. This is like trying to study when you are preparing to go out on a hot date. So, people who are bystanders to a violent crime are likely to remember more than the victims. The bystander would be closer to the optimum arousal level, whereas victims would be too highly aroused.

There is evidence that, overall, memory does follow the basic pattern of the Yerkes–Dodson law. However, the situation is more complicated than it first seems. Specifically, the ability to remember details under different levels of emotional stress depends on the type of details. At high levels of emotion, memory for peripheral details (e.g., the color of a car, someone's clothing, the actions of bystanders, etc.) is worse. However, memory for central details (e.g., what a robber said) is better. This contradicts the Yerkes–Dodson law but it is consistent with the **Easterbrook hypothesis**. For the Easterbrook hypothesis (Easterbrook, 1959), at higher levels of emotional intensity people restrict their attention to a narrower range of details. Attention is more focused (Kensinger, Garoff-Easton & Schacter, 2007; but see Laney, Campbell, Heuer, & Reisberg, 2005), a process called **cue utilization**. At normal emotional stress levels, people notice a variety of things in their environment, giving a more attention to various details. However, during an emotional event attention focuses in on the principal parts of that event and less on other irrelevant details (see also tunnel memories, discussed in Chapter 12). Thus, peripheral details are less well remembered, whereas the central details are better remembered. For example, if you encountered two people in a nonstressful event you might remember their faces equally well. However, if you met them as part of a stressful event, where one was a bank robber and another was a person in line, the cue utilization that occurs as a result of narrowing your attention would lead you to pay more attention to, and thus better remember, the robber's face relative to the other customer's face.

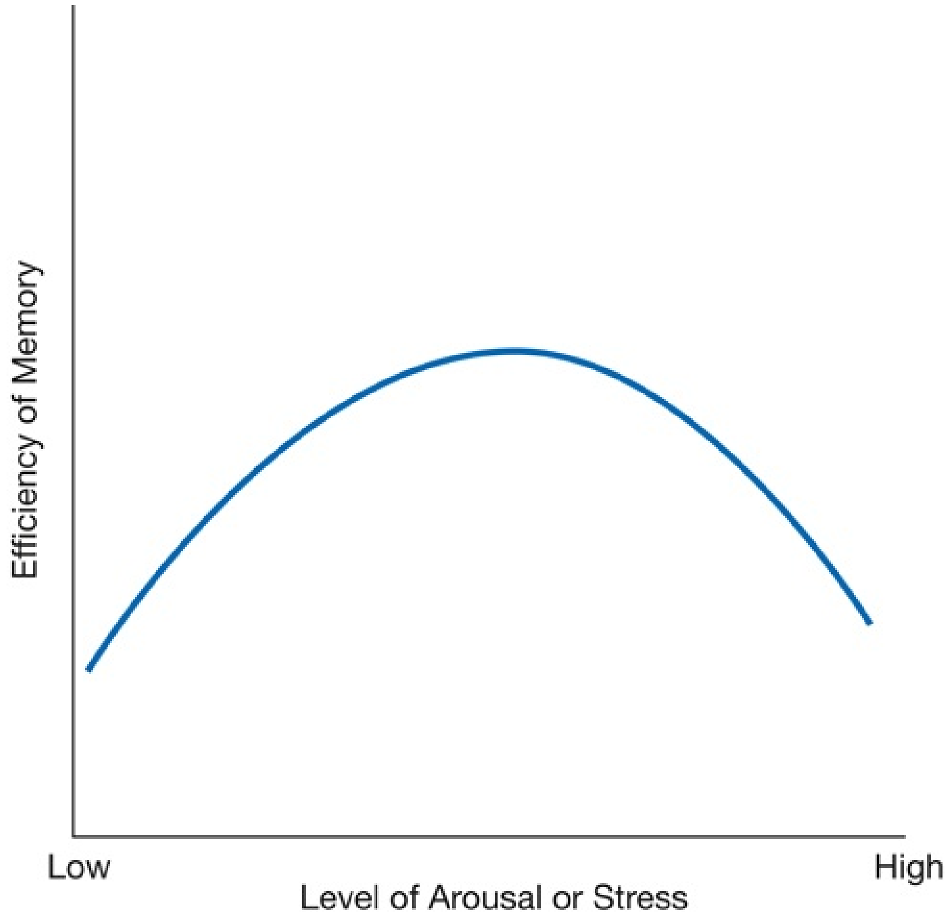

FIGURE 14.3 *The Yerkes–Dodson Law*

It should be noted that, although high levels of emotion can lead to more accurate memory for a narrower range of information, this does not mean that people do not report remembering a wide range of things. Although accurate memory is present for the details focused on, people can still fill in their memories with what they *expect* to be present in the rest of the situation based on their schemas and scripts. For example, people who see both emotional and neutral pictures show boundary extension effects (see Chapter 5) of similar magnitudes (Candel, Merckelbach, & Zandbergen, 2003). In effect, they are still interpreting their memories of the pictures they have viewed using their expectations of what likely extended beyond the boundaries of the pictures.

A good example of the influence of emotional intensity is the **weapon focus effect**, which is an increase in memory for a weapon (such as a gun, knife, cleaver, etc.) along with a decline in memory for other details (Maass & Köhnken, 1989; Steblay, 1992; see Fawcett, Russell, Peace, & Christie, 2013 for a meta-analysis). Recordings of eye movements while watching pictures that depict a crime show that people spend more time looking at what a person is holding if it is a weapon than if it is a neutral object (Loftus, Loftus, & Messo, 1987). This even occurs when a weapon is present but not involved in a violent action (Kramer, Buckout, & Eugenio, 1990). The barrel of a gun or the blade of a knife is a point of great interest to people and they spend a lot of time looking at such things. At some level, people want to know whether the weapon will be used against them. This increased attention to a weapon increases memory for it and decreases memory for other aspects of the event, such as a perpetrator's face. While some of the weapon focus effect is due to the unusualness of a weapon (Pickel, 1998), there is also added memory disruption because it is a source of danger.

PHOTO 14.1 *Memory for eyewitnessed events can be influenced by the level of arousal experienced—attention and memory tends to narrow in on central aspects of the event, as with the weapon focus effect*

Source: Monkey Business Images/Monkey Business/Thinkstock

John Dean's Memory

One of the more famous cases of memory in legal proceedings is John Dean's memory of the cover-up of the Watergate break-in during President Nixon's administration. This incident led to the president's resignation. John Dean, one of the White House advisors, testified before Congress about the cover-up in terms of what was going on in the White House. John Dean testified against President Nixon and the other coconspirators. What was remarkable about Dean's testimony was the number of conversations he claimed to remember and the degree of accuracy with which he remembered them. (His initial statement to Congress was 245 pages long.) His memory was so remarkable that reporters nicknamed him "the human tape recorder."

The interesting thing is that, soon after John Dean had given his testimony, real tape recordings emerged that Nixon had secretly made of White House conversations. At that point, it was possible to compare Dean's memory with the recordings and a scientific study of memory for conversations that had legal implications. And this is just what was done (Neisser, 1981).

In comparing the initial testimony concerning things that were claimed to have been said and the actual conversation on the tapes, John Dean hardly ever got it exactly right. Many things that he claimed were said were never actually said at specific meetings. For example, with regard to one White House meeting, Dean claimed that Nixon had asked him to sit down, had asked Halderman (another aid) to keep him posted, and had praised Dean for doing a good job. Also, John Dean claimed that he himself had made statements about not really wanting to take credit for his efforts and that the cover-up would eventually unravel. The tapes revealed that none of these statements was made during the meeting in question.

However, a comparison of Dean's statements and the tapes also indicated no attempt to lie on Dean's part. The tapes do corroborate important points in Dean's testimony, such as the fact that the White House was aware of and was involved in the cover-up. Often the distortions in Dean's testimony reflected a schematization of his prior memory. His memory reflected the events in a cleaned-up fashion. Also, Dean misremembers himself as playing a more central role in the conversations than was the case. This self-centered bias is an expected aspect of anyone's memory of an event. This is because our memory of an event includes both the things that objectively occurred and our own subjective thoughts and emotions that would be stored as part of the memory trace. Any act of remembering will involve these components.

Stop and Review

While eyewitness testimony is generally accurate, it can be altered. The way a question is worded can bias how people misremember an event. People also incorporate misleading information into their reports, either because the original memory is altered or replaced, because a misleading memory for has blocked access to the original, accurate memory, or because of problems with source memory. Eyewitness memory is affected by a witness's level of arousal. Consistent with the Yerkes–Dodson law, overall memory is worse at high levels of arousal. This is because attention during encoding is focused on fewer, critical details, consistent with the Easterbrook hypothesis. This is seen in the weapon focus effect. John Dean's memory provides evidence for the idea that an eyewitness may be inaccurate for some of the details but be spot on for the gist of a crime.

EYEWITNESS CONFIDENCE

Is there any way to assess how accurate eyewitness reports are, especially when there are few to no other sources of corroborating evidence? Intuitively it seems that eyewitness confidence should be an indicator of memory accuracy. However, metamemory, the monitoring of one's own memory performance, is imperfect (see Chapter 15). The same applies to eyewitness accounts. It is quite possible to have people who are very confident that an innocent person committed a crime. For eyewitness identification, the average overall correlation between accuracy and reported confidence is quite low: $r = .29$. If only people who actually select someone are considered (leaving out people who say that they do not see the offender in a lineup), the correlation improves somewhat: $r = .41$ (Sporer, Penrod, Read, & Cutler, 1995). Still, the relation is far from perfect. In terms of memory for details, confidence is more reliable for central as compared to peripheral aspects of the event (Roberts & Higham, 2002). Thus, it is possible to have people who are very confident and wrong.

Eyewitness confidence is influenced by a number of factors. One is **postidentification feedback**, which is information about the quality of an eyewitness's report. For example, if positive feedback is given to a witness, such as "Good. You identified the suspect," then the confidence in memory increases, compared to when no feedback is given. This can also lead witnesses to embellish claims about the quality of their view of the crime, the clarity of their memory of the event, and the speed with which they remember identifying the person (Wells & Bradfield, 1998, 1999). Of course, there is no way for such a comment to actually improve any of these qualities of memory.

Also, telling a witness what other witnesses reported increases confidence. For example, after a lineup identification for an offender, if a witness is told that another witness picked the same person, then confidence increases for the choice. However, if the person hears that another witness picked someone else, confidence decreases (Luus & Wells, 1994). Thus, the relation between identification accuracy and confidence can become distorted by subsequent information.

Witness confidence is also influenced by how many times questions are asked. The more people are asked about an aspect of a crime or an accident, the more confidence they have in their memories. This is noteworthy in that, by and large, from what you know about memory already, the passage of time typically makes memories worse, not better, even though confidence is increasing over time with more retellings. This increase in confidence even occurs for misleading postevent information (Shaw & McClure, 1996). Again, this increase in confidence as a result of repeated questioning is unrelated to the accuracy of the memory for the event.

Repeated questioning makes information easier to access and more salient in memory (remember that it is impossible to probe a memory without changing it). Increased retrieval fluency may lead people to be more confident in their accuracy (Shaw, 1996; but see Odinot & Wolters, 2006). This is important because judges and juries are often swayed by the confidence a witness appears to have in the memories that are reported. By the time a witness gets to trial, the same questions have been answered many times, thereby increasing confidence without a corresponding increase in accuracy. To make matters worse, efforts to make people aware of the relationship between their level of confidence and memory accuracy may either have no effect or actually worsen the relationship (Robinson & Johnson, 1998). Finally, eyewitness confidence can be influenced by external motivation to remember accurately. This is illustrated in detail in the Study in Depth box above.

STUDY IN DEPTH

To address the issue of how eyewitness confidence and motivation can affect eyewitness accuracy, let’s look in detail at a study by Shaw and Kerr (2003). This study assessed the eyewitness memory of 75 students at Lafayette College. An event was identified by the researchers for which the students would be tested later. Specifically, during the third week of the academic term, the students heard a nine-minute presentation from the college counseling center.

Five days after the target event, the students were given a surprise memory test about what they remembered from that event. This memory test consisted of a randomized list of 12 three-alternative multiple-choice questions about the classroom visitor's appearance and what she talked about. The students were also asked to rate their confidence in their answers to each question. The students were allowed to go through the memory test at their own pace.

Critically important for this study, for half of the students there was no extra motivation to remember accurately (the control group). However, the other half (the experimental group) was told that they could get a prize if their answers were correct. Specifically, the person with the most correct answers would get $25, and the 10 next-highest scorers would get a candy bar of their choice. Thus, half of the students were extra motivated to be correct and half were not. How did the additional motivation affect the memory of the students?

This study found that extra motivation did not alter the accuracy of the memory reports and confidence ratings. People were similarly accurate no matter which motivation group they were in. However, motivation did affect the relationship between accuracy and confidence. For the control group, the correlation between accuracy and confidence was relatively good: $r = .44$. However, for the students with the extra motivation in the experimental group, the correlation was horrible: $r = .05$. Essentially, by encouraging people to try harder a great deal of effort is associated with each memory retrieval attempt. As such, it becomes harder for people to identify what was easy to remember and what was difficult. As a result, the usefulness of the confidence ratings drops tremendously. This is important because eyewitnesses to accidents and crimes are often motivated to try hard to remember. Such an external motivation may end up backfiring.

Stop and Review

Although eyewitness confidence is often used as an indicator of accuracy, the real relationship between them is lower than would be desired. Moreover, this relationship is worsened by a number of factors, including reinforcing feedback, repeated attempts to remember, and external encouragement to try to remember more accurately.

THE COGNITIVE INTERVIEW

Given the problems with eyewitness memory that can make it so error prone, can anything be done to improve these reports? Research on eyewitness memory has led to information gathering methods to increase accuracy and decrease the impact of misinformation. The most prominent of these is the **cognitive interview**. This technique uses basic memory principles to maximize the amount of correct information and minimize the amount of incorrect information from a witness (Fisher, Milne, & Bull, 2011; Geiselman et al., 1984; Geiselman, Fisher, MacKinnon, & Holland, 1985; see Memon, Meissner, & Fraser, 2010 for a meta-analysis). The cognitive interview does this by focusing on five retrieval processes.

The first is to use the principles of encoding specificity and mood-dependent learning (see Chapter 7). There should be some attempt to reinstate the external and internal contexts of the event. This can include having people imagine being back at the scene and feeling how they felt at the time. Reinstating the context serves as a retrieval cue, making it more likely that people can access information in memory. As a reminder, context is most likely to have an effect on memory retrieval during recall, with weaker memory traces—just as in the case of police interviews.

Second, because people sometimes retrieve only partial information, as with the tip-of-the-tongue state (see Chapter 9), witnesses are encouraged to report whatever they can, however partial or insignificant it may seem to them at the time. For example, if a witness cannot remember someone's name but can remember how many syllables it had or what letter it began with, then it should be reported. Information, even in a fragmentary state, can potentially be useful to investigators.

Third, there are often many retrieval pathways to a given piece of information. When we forget information, we may be able to retrieve it later if we take a different approach (see Chapters 7 and 8). This retrieval can be accomplished by reporting an event in a variety of orders. By starting at different points, this emphasizes different types of information and different details are reported. This enhances eyewitness reports.

Fourth, a person may report information from a different perspective (see Chapter 9). Altering perspective may make some information more salient and more likely to be reported. As such, the witness's report is more complete. Alternative perspectives provide alternative retrieval pathways, allowing information to be remembered that might otherwise have been missed.

Finally, questioners are discouraged, wherever possible, from interrupting a witness's report. By disrupting people, the flow of the natural retrieval plan is dis turbed, and some of the more weakly stored information might not be reported. This is similar to the part-set cuing effect (see Chapter 9), in which providing people with part of a learned set of information can actually result in the probability of recalling a given item decreasing rather than increasing. In short, interrupting people disrupts their idiosyncratic retrieval plans, thereby worsening memory performance.

Improving Your Memory

Most of what you need to remember does not come from witnessing an accident or a crime (thankfully). That said, there are some lessons to be learned and applied to your everyday situations. For example, you can take the techniques that are used for the cognitive interview and apply them to your everyday memories for events. This can include trying to mentally reinstate the context and emotional state you were in when you experienced an event, not being shy about using whatever partial information you may have available, trying different ways of thinking about the event, and giving yourself some time to let weaker aspects of the memory come to mind. You should also adopt a healthy skepticism of your confidence in your event memories. Remember, the accuracy–confidence correlation is generally positive. That said, you can be really confident about something and still be wrong. Finally, try to keep the limits of memory in mind when listening to other people describing events that they remember. They may be inaccurate about things, even things that they are confident about. This healthy skepticism can even be useful if you ever serve as a juror for a trial.

The cognitive interview has been modified over time as better ways of extracting accurate eyewitness reports have been understood. An enhanced cognitive interview has been developed that places the witness more in control of the retrieval of memories from an event (Fisher & Geiselman, 1992). Moreover, a shortened version has been devised to elicit the needed information in less time (Bensi, Nori, Gambetti, & Giusberti, 2011).

The cognitive interview is an effective eyewitness memory tool. Using it can boost the reports of accurate information by more than 50% without noticeable changes in how much incorrect information that may be reported (Fisher, Geiselman, & Amador, 1989). The cognitive interview takes more time to administer than a standard interview. However, given the amount of extra work that might be required without that information, the cost is well worth it.

Stop and Review

Although eyewitness memory is imperfect, by using what we know about memory we can develop techniques that increase accuracy. The cognitive interview does this by taking into account what is known about the influences of learning context, partial retrieval, hypermnesia, and part-set cuing on memory to avoid situations that deter accurate remembering.

EYEWITNESS IDENTIFICATION

An important task for an eyewitness may be to identify the people involved, particularly the culprits of crimes. An eyewitness must reliably remember individuals to accurately identify them later. However, as we have seen, people are prone to forgetting, which can cause them to make errors. In the case of eyewitness identification, this forgetfulness can lead to one of two undesirable outcomes: (1) failing to identify a perpetrator or (2) misidentifying an innocent person as the perpetrator. In cases of DNA exoneration of previous convictions, erroneous eyewitness identification was the primary cause of the imprisonment of innocent people. A number of things can influence a witness's memory of a person involved in a crime. Some of these are beyond the control of the legal system, such as whether a perpetrator was carrying a weapon (which reduces identification accuracy), how good the lighting was at the time, how far away the perpetrator was from the eyewitness (Lampinen, Erickson, Moore, & Hittson, 2014), and how much stress the eyewitness was experiencing at the time (Valentine & Mesout, 2009). However, steps can be taken to increase identification accuracy for other factors (Clark & Godfrey, 2009; Wells et al., 2000; Wells, Memon, & Penrod, 2006).

Mug shots

Mug shots are a standard way to help identify perpetrators of crimes. Essentially, an eyewitness is shown a series of photographs of people who have been involved in previous crimes. If a witness can identify the perpetrator from this set of faces, the police can more quickly solve the crime. However, mug shots can also have negative effects on memory. If people are shown a series of mug shots and the perpetrator is not among them, the eyewitness may sometimes pick out another person as the criminal. When people incorrectly identify someone from mug shots, their ability to identify the perpetrator later is lower than for people who do not incorrectly identify someone (Gorenstein & Ellsworth, 1980). Essentially, memory for the selected mug shot interferes with, and makes it harder to retrieve, the memory of the face of the perpetrator. However, this occurs only if people commit to identifying a face in the mug shots as the perpetrator (Dysart, Lindsay, Hammond, & Dupuis, 2001). No memory deficit comes from just viewing the pictures.

When the perpetrator was not among the mug shots, witnesses may later pick out another person whose mug shot was viewed earlier, even if that person was not identified during that time (Memon, Hope, Bartlett, & Bull, 2002). Witnesses may pick these people because they seem familiar, not realizing that it is because they were among the mug shots. People have better memory for whether or not they had seen a face before than remembering where they had seen that face (Brown, Deffenbacher, & Sturgill, 1977). So, problems in source monitoring with mug shot viewings can lead to errors in eyewitness identification.

A procedure that also focuses on face memory is to have a sketch artist generate a composite drawing of a perpetrator. This is a form of recall memory. Unfortunately, the individual drawings created using this method are poorer than one would hope. That said, morphing the drawings from several witnesses can produce a more accurate image (Wells & Hasel, 2007). The poor recall observed here is likely due to the fact that people do not encode faces as sets of features but in a more holistic fashion.

Unconscious Transference

An important aspect of eyewitness memory that investigators cannot control is **unconscious transference**, which occurs when a person mistakenly identifies an innocent bystander as the perpetrator (Ross, Ceci, Dunning, & Toglia, 1994). In such cases, a witness remembers seeing the offender and others but then becomes confused. So, an innocent bystander is incorrectly remembered as being the person who committed the crime.

A particularly compelling description of unconscious transference is provided by Baddeley, Eysenck, and Anderson (2015, p. 344). In 1975, Donald Thompson, an Australian psychologist, was accused of raping a woman in her apartment and leaving her unconscious. The day after the rape he was picked up by the police. The woman who had been raped had accused him as being the culprit and identified him out of a police lineup. However, he was clearly innocent of the crime. Why? Well, at the very time the rape was happening he was far away giving a live television interview on the unreliability of eyewitness testimony. Also part of that interview was a member of the Australian Civil Rights Committee and the Assistant Commissioner of Police. When Thompson explained to the arresting officers that he had these people as witnesses for his alibi, they replied "Yes, and I suppose you've got Jesus Christ and the Queen of England, too!" So, how could such a false accusation from the victim occur as part of this tragic event? Well, just prior to and during the rape, the woman's television was turned on and this live broadcast was what was being played. She accurately remembered Thompson's face as part of the event (in that it was on the television screen) but mistakenly remembered how he was involved.

What happens with unconscious transference is that people remember seeing the person as a bystander but also remember that person as the perpetrator as well. This is a memory blending theory of unconscious transference (Ross et al., 1994). This may occur because people know that each person was involved in the event but they may have trouble remembering the role each person played (Kersten, Earles, & Upshaw, 2013). Thus, an eyewitness may remember that two people were involved, one as the perpetrator and the other as a bystander, but then later confuse their roles. Another view is a source monitoring theory of unconscious transference (Read, 1994). Here, people remember a person but fail to remember the situation in which they interacted with that individual. As a result, people may be more likely to misattribute the source of a memory as a case of remembering the person as the perpetrator of a crime.

Lineups

One way to improve eyewitness identification is proper lineup procedure. Keep in mind that, because of how memory works, there is always some forgetting of details and eyewitness memory is not perfect. Identification of a suspect is a recognition process. People are comparing their memories with what is presented in the environment, such as faces in a police lineup. During identification, people make judgments based not only on how well a given person matches their memory but also how well the different people in the lineup compare to one another in terms of how much they resemble the offender. This is the **relative judgment principle** (Wells, 1984; but see Fife, Perry, & Gronlund, 2014). According to this principle, people may select someone from a lineup not because this was the person the witness saw but because, compared to the others, that person most closely resembles the criminal.

So, lineup similarity—the physical resemblances of others in the lineup—is important. Lineups created with fillers who do not resemble a suspect much are biased in favor of the witness choosing the person who most closely resembles their memory of the offender. However, when lineup fillers at least fit the basic description given by the witness, people need to use memory more carefully and their selections are more diagnostic (Wells, Rydell, & Seelau, 1993). With similar lineup fillers, the identification of guilty suspects is roughly the same as when they are dissimilar but the identification of innocent suspects decreases considerably (Lindsay & Wells, 1980).

Eyewitness identification can also be influenced by the instructions given to a witness. A critical factor is whether the instructions include a statement telling the witness that the perpetrator might not be present. This instruction explicitly opens up the possibility of the witness not identifying anyone. Without this simple instruction, there is a strong bias to select *someone*. As a result, an innocent person may be identified just because he or she closely resembles the perpetrator. In comparison, with this instruction, people are less likely to feel compelled to pick someone and the false identification rate drops dramatically (Malpass & Devine, 1981). In general, the rate of false identification drops by about 42% when this instruction is included. The rate of not selecting a perpetrator drops by only about 2% (Steblay, 1997; Steblay & Phillips, 2011).

Finally, eyewitness identification is also influenced by how the lineup is presented. The traditional lineup—what you see in movies and cop shows—is a **simultaneous lineup**, where all of the alternatives are shown together and the witness is asked to select one. Another type is a **sequential lineup**, where the witness sees one person at a time. Keeping in mind that people make decisions using a relative judgment principle; witness identification errors are more likely with a simultaneous lineup than with a sequential lineup (Lindsay & Wells, 1985; see Steblay, Dysart & Wells, 2011, for a meta-analysis). It is easier for a witness to make relative comparisons among people when they are presented simultaneously. As such, relativistic judgments are more likely to be made. However, with sequential lineups, people are in a position of being forced to compare the person they are seeing at the moment with their memory of the perpetrator. This is because witnesses do not know whom they will be seeing next or how many people they will see altogether. Using a sequential, as opposed to a simultaneous lineup, greatly lowers false identifications, with little to no effect on positive identifications of actual offenders (but see Clark, Moreland, & Gronlund, 2014).

Stop and Review

As with other memories, the act of using a memory can change it. Having seen a face previously in mug shots can mistakenly lead people to think that it was the face of the perpetrator. Also, an eyewitness may make an error of unconscious transference and misremember a bystander as the perpetrator. Because people may be prone to use relative judgments, it may be better to have sequential rather than simultaneous lineups. In addition, lineup accuracy is increased if people are explicitly reminded that they can say "not present" if the person is not there.

JURIES

The influence of memory on legal matters affects areas other than gathering testimony from eyewitnesses. Another setting where the operation of memory is import ant is for juries. Jury trials, while fairly efficient, are often not as crisp and clean as one would hope. In this section we look at two ways that memory can influence jury decisions apart from other cognitive factors that can influence jury decision-making (Salerno & Diamond, 2010). These are the order in which information is encountered and the ability of juries to disregard inappropriate information.[2]

Information Order

When jurors hear evidence, they try to mentally construct an understanding of the event in the form of a coherent story, much like what happens with autobiographical memory (see Chapter 12), only in this case the memory is for other people's experiences (Pennington & Hastie, 1986, 1988). The memories of jurors are affected by the order in which they learn information, just like other settings. This order influences the decisions rendered later. There are two ways to assess how information order affects jury decisions. The first is a step-by-step process in which people render preliminary decisions after each piece of information is given. In these circumstances, people show a recency effect (Pennington & Hastie, 1992). That is, decisions are more influenced by the information they learned most recently. The most recent information is most available in memory so people are more likely to rely on it.

PHOTO 14.2 *It is important to understand how memory works when considering how people make decisions on a jury; each juror is prone to the same memory distortions*

Source: IPGGutenbergUKLtd/iStock/Thinkstock

The other way to assess the influence of information order is to have people make decisions after all of the information is given. Here, one of two things can happen. If people are given background information, such as the motive for a killing, then decisions show a recency effect. However, if people are not given background information but are presented only with reports from various witnesses, then people show a primacy effect (Kerstholt & Jackson, 1998). This happens because background information gives people a starting point and they are more willing to adjust their opinions based on new information. However, without this background information people try to make a coherent story with the information they have. As a result, they need to keep more information of their own creation active in working memory and are more reluctant to alter their prior understanding of the events, which would require more mental effort.

In addition, jurors may hear contradictory testimony, sometimes from the same witness. How is memory affected by hearing these inconsistencies? Are jurors more affected by the initial statement or the later, contradictory statement? As it turns out, jurors are affected by both. For inconsistent testimony from a given witness, jurors remember and note both statements and tend to place less emphasis on such testimony when making their decisions (Berman & Cutler, 1996).

Inadmissible Evidence

A problem that can arise before a jury trial (as with pretrial publicity), or during the trial itself, is when jury members are exposed to inadmissible evidence. If this happens, a judge has a couple of choices. One is to declare a mistrial and the other is to instruct the jurors to disregard or ignore the inadmissible evidence. Clearly, the second alternative is preferable if the jury can be trusted to do so because it makes the process quicker.

The instruction to disregard evidence is essentially a directed forgetting instruction (see Chapter 8). The question here is how well does the instruction to forget work in a real-world setting that has serious implications for a defendant on trial? When memory for inadmissible evidence is tested for using a directed forgetting paradigm, jurors' memories of the inadmissible evidence are poorer than for admissible evidence. So, there is some success in forgetting the information. However, when looking at assessments of a defendant's attributes (e.g., friendly, dishonest, etc.) and decisions to convict or acquit, there is a clear influence of the inadmissible evidence. The presence of damaging inadmissible evidence biases jurors toward a guilty verdict, whereas supporting inadmissible evidence biases jurors toward a not guilty verdict (Golding & Hauselt, 1994; Thompson, Fong, & Rosenhan, 1981). Generally, people continue to use information they were supposed to disregard to make attributions about a person (Wyer & Unverzagt, 1985). This is because the memories for inadmissible information may have been suppressed and people have difficulty accessing the source information in long-term memory (Bjork & Bjork, 2003). Thus, jurors may remember the information but not where it came from. Thus, they forget that they are supposed to forget it. In essence, this is also a form of the sleeper effect.

This influence of the to-be-forgotten information on decision-making is also influenced by jurors' opinions about the source or nature of the information. Directed forgetting is less efficient and the opinions are more biased when the jurors believe that information is accurate and relevant to the defendant, such as when the information is described as confidential but inadvertently presented. However, directed forgetting is more efficient and opinions much less biased when the jurors believe that the information is inaccurate and irrelevant to the defendant (Golding, Fowler, Long, & Latta, 1990). For example, forgetting is more efficient if the jurors were told that the information actually referred to another person in a different case. Alternatively, if the jurors are suspicious of the source of the inadmissible evidence, it will not affect their decision-making

(Fein, McCloskey, & Tomlinson, 1997). For example, if people are exposed to pretrial publicity that is damaging to the defendant and then later learn that this information was leaked by a source trying to unfairly discredit the defendant, then jurors successfully forget that information.

There are clear influences of inadmissible evidence on the decisions of individual jurors. When the evidence is deemed relevant and comes from a reliable source, people have a hard time forgetting it so that it does not influence their subsequent decisions. It is still in long-term memory and has an implicit effect on thinking. While this may be troubling, the influences of this ineffective forgetting can be mediated or softened during the deliberation process, where the jurors discuss the case with each other and come to a consensus about what verdict to render (London & Nunez, 2000). Here, the collective memory efforts of the jury help dampen the implicit influences of to-be-forgotten and inappropriate information. The information is so weak to begin with that it cannot compete with the stronger, explicit knowledge that is being openly discussed during deliberation.

As a final point, not all inadmissible evidence comes from external sources. Sometimes it comes from the jurors themselves. When people think about events, they may think about the way things might have been different. This is called **counterfactual thinking**. When people engage in counterfactual thinking, they are likely to focus on behaviors that are outside of a person's normal routine. Jurors are more likely to award a victim a larger level of compensation if the defendant did something out of the ordinary because it is easier to imagine that person doing some thing different. However, if the victim did something outside of his or her normal routine, then the juries tended to award a smaller compensation. It is as if they are, in part, unconsciously blaming the victim. Moreover, the smaller the size of people's working memory spans, the less likely they are to suppress these irrelevant thoughts when making decisions (Goldinger, Kleider, Azuma, & Beike, 2003).

Stop and Review

Memory is important for juries. Their decisions are influenced by the order in which information is encountered. They also vary in their effectiveness at suppressing, or forgetting, inadmissible evidence. Even when they try to conform to instructions, the decisions juries reach can be biased in the direction of the inappropriate information due to unconscious processes. Finally, the collective deliberation process can mitigate the distorting effects of memory.

PUTTING IT ALL TOGETHER

Memory has practical value that is important for our society to be well-functioning and fair. This is seen most clearly in the legal arena. Some aspects of our memories give us trouble. Problems can arise when we lose knowledge of the source of a memory and our reports of events become distorted and incorrect. This may happen when we are asked questions whose wording can be biasing; when we encounter misinformation information; and when we become confused about who a perpetrator was and who were just bystanders or faces in a set of mug shots or a lineup.

Other aspects of memory can be used to bring about fair and just outcomes. While our emotions can get in the way by limiting the overall scope of our knowledge, they can also serve as a focusing lens to lead us to better remember more critical, central details. This is the distinction between the Yerkes–Dodson law and the Easterbrook hypothesis. Furthermore, while our confidence in our memories is not ideal it does have some merits, so long as we guard against situations that can throw confidence and accuracy out of whack. This can include comments and feedback that are given later, as well as the number of times a memory is drawn out of us. The study of human memory and legal issues can be brought together, as with the cognitive interview, to provide our society with guidelines to increase to the effectiveness of the pursuit of justice.

Finally, memory also has an important influence on juror decision-making. In some circumstances, the testimony that we hear most recently has a greater influence, a kind of recency effect; whereas, in other circumstances, there is a preference to base decisions on the earlier information. As jurors, we also may find it hard to forget information that was deemed inadmissible, especially when that information may seem relevant. That said, the jury deliberation process, in which we work together, has the ability to mitigate and correct some of these biases and errors.

STUDY QUESTIONS

1. How can an eyewitness's memory be altered by what they hear after witnessing an event?
2. What are some likely effects of misleading postevent information?
3. What are some of the theoretical explanations for the misleading postevent information effect?
4. How does an eyewitness's arousal level at the time of an event affect

memory? What theory best captures this?

5. How does the presence of a weapon during a crime affect memory?
6. What do the findings about John Dean's testimony tell us about eyewitness memory?
7. What is the relationship between eyewitness confidence and accuracy? How can this be altered, and with what outcome?
8. How does the cognitive interview work to produce more accurate memory reports?
9. How is eyewitness identification affected by the use of mug shots? By different types of lineups? By things that are said by an investigator?
10. How is eyewitness identification affected by the presence of bystanders, in terms of unconscious transference?
11. How does the order in which jurors hear things affect their memories?
12. What happens in the memories of jurors when they are instructed to disregard inadmissible evidence? How does this influence their decision-making?

KEY TERMS

- blocking theory
- cognitive interview
- confidence
- counterfactual thinking
- cue utilization
- Easterbrook hypothesis
- eyewitness testimony
- lineup similarity
- memory replacement theory
- misleading postevent information
- postidentification feedback
- relative judgment principle
- sequential lineup
- simultaneous lineup
- source monitoring theory
- unconscious transference
- weapon focus effect

- Yerkes-Dodson law

EXPLORE MORE

Here are some additional readings that you can use to further explore some of the ideas about how memory can impact legal issues.

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NOTES

1 A commonly cited study is by Loftus and Palmer (1974), in which people were asked, "How fast were the cars going when they smashed/collided/bumped/hit/contacted each other?" What was found was that the speed estimates varied, by nearly 10 miles per hour, depending on which verb was used. However, this effect has been difficult to replicate (Lipscomb, Bregman, & McAllister, 1985; McAllister, Bregman, & Lipscomb, 1988; Read, Barnsley, Ankers, & Whishaw, 1978; Read & Bruce, 1984).

2 For a compelling description of jurors' understanding of memory principles during a murder trial, see Brainerd (2013).

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CHAPTER 15

Metamemory

Much of how our memories affect thinking and behavior occurs out of conscious awareness. Still, we do have some conscious insights into our own memories, with the experience of remembering differing for different memories. There are also instances in which we forget and have some awareness of whether we have this knowledge hidden away somewhere. To remember effectively, we need some conscious awareness and control of our own memories. This is **metamemory**—the awareness of one's own memory. This refers to both the contents of memory and how to control it.

There are a number of ways to look at metamemory. First, we examine theories of metamemory, and then we cover a number of phenomena, including our ability to judge when we have learned something or whether we will later remember things that are currently forgotten. We also look at how we know that we *don't* know something. After this there is some coverage of issues involved in the phenomenology of memory, such as the experience of an act of remembering (what does it feel like to remember or forget), and how what we currently know biases that we remember from the past. Finally, we explore how to use what we know about our own memories to improve them, including the use of mnemonics and some consideration of people who have exceptional memories.

GENERAL PROPERTIES AND THEORIES OF METAMEMORY

Before addressing various aspects of metamemory, let's go over some basic concepts and theories. First, we need to cover the difference between cues and targets. After that, there is an overview of general theories on how metamemory judgments are made—namely, the cue familiarity, accessibility, and competition hypotheses. Keep in mind that metamemory judgments can be affected by processes that influence cognition more generally. For example, metamemory judgments vary in their accuracy depending on what time of day it is, which is correlated with level of arousal (Hourihan & Benjamin, 2014).

Cues and Targets

As a point of terminology, memory traces that people make judgments about are called **targets** and the questions or prompts are called **cues**. So, if someone were to ask you if you remember your thirteenth birthday, your memory for the birthday would be the target and the question would be the cue.

In a review, Schwartz (1994) outlined two types of information that are used to make metamemory judgments. Target-based sources are information from the memory trace about which the judgment is made, including information that has been retrieved from memory, as well as the ease with which it is recovered. Target-based sources are especially important in judgments of learning. In comparison, cue-based sources are information gleaned from a memory cue, such as a question or prompt. Metamemory judgments are better in proportion to the familiarity of the cue information. So, if someone asks you a question about a topic that you are relatively familiar with, you are more inclined to say that you know the answer based on how familiar the concepts in the question seems. Now, let's look at three general theories of metamemory.

Cue Familiarity Hypothesis

According to the **cue familiarity hypothesis** (Metcalfe, 2000; Reder, 1987), metamemory judgments are based on the familiarity of the information in a cue. That is, the emphasis is on cue-based sources of information. The more familiar the contents of a cue are, the more likely that people will judge that the knowledge is in memory. Imagine if someone asked you if you know your grandmother's maiden name. If you know a lot about your family, you might recognize this as a familiar topic and say to yourself, "this is something I know." However, if you are not all wrapped up in your family's history, you might recognize this as a topic you know little about and say to yourself, "I have no clue."

Accessibility Hypothesis

According to the **accessibility hypothesis** (Koriat, 1993, 1995), metamemory judgments are inferential. People can make inferences about what is in memory based on information at hand, including partial retrievals. There are two sources of information that are used to make these metamemory inferences. One is the *amount* of information that is activated when a judgment is made. The more information that is activated, the more likely that the knowledge is in memory. For example, if you can't think of someone's name but you know what letter it begins with, how many syllables it has, and so on, then you possess a lot of information and you will be more likely to judge that the name is in memory.

The other source of information is the *intensity* of the activated memory traces. This includes the ease of access, the vividness of any imagery, how specific the information is, and so on. The stronger the retrieved information, the more likely the knowledge is in memory. For example, if you are asked what your best friend's mother's maiden name was, a number of names might be activated in memory but only very weakly. As a result, you would decide that you do not know this. Comparing the cue familiarity and accessibility hypotheses, the first is more apt for metamemory decisions are made under time pressure, otherwise the second is more appropriate (Benjamin, 2005; Metcalfe & Finn, 2008b).

Competition Hypothesis

For the **competition hypothesis** (Schreiber, 1998), metamemory judgments are influenced by the number of memory trace competitors that are involved in retrieval. Thus, the emphasis here is also on target-based sources of information. Metamemory judgments are greater with less competition. When only a few traces are involved, the search process is fairly targeted and is likely to produce the desired information. In contrast, if a large number of traces are involved, resulting in interference, then it is less likely that the knowledge is going to be retrieved. The more competition among the relevant traces, the more difficult retrieval will be.

Stop and Review

Metamemory judgments involve a cue and a target. The cue is the question about one's memory, and the target is the contents of the memory itself. There are a number of theories of metamemory. One is that decisions are based on the familiarity of the cues. Another is that judgments are based on a partial memory search. Finally, there is an idea that metamemory judgments reflect how much interference is experienced during retrieval.

KNOWING WHAT IS KNOWN

So, how well do people know their own memories? This includes assessments of how well information has been learned, whether information that has been forgotten is still known, and how we know that we don't know something. The next sections address these issues.

Judgments of Learning

When learning, it is helpful to know how well new materials are being stored in long-term memory. Information that is poorly learned should be studied more, and information that is well learned does not need as much further study. Estimates for how well people have learned something are called **judgments of learning**, or **JOLs** (Arbuckle & Cuddy, 1969). Studies of JOLs have shown that people are between poor and horrible at assessing how much has actually been learned. The question is, why?

One theory of why JOLs are so poor is the **inability hypothesis**, which is that JOLs are poor because people have little conscious awareness of their own mental processes (Nisbett & Wilson, 1977). We lack the ability to assess our own learning because we lack sufficient insight into ourselves and our memories. For this view, so much information is below conscious awareness that we are almost guaranteed to be wrong more often than we are right.

An alternative is the **monitoring-retrieval hypothesis**, which states that JOLs are poor because people are assessing whether they can retrieve information. When JOLs are made soon after the information was encountered, that information is still in working memory. As such, people think that the information is better learned than it actually is. If some delay or interruption were present, then people could more accurately assess whether the material can be retrieved from long-term memory.

These theories were tested by Nelson and Dunlosky (1991; but see Kimball, Smith, & Muntean, 2012). They elicited JOLs either immediately or after a delay. If the inability hypothesis is correct, then a delay should not matter. However, if the monitoring-retrieval hypothesis is correct, then, after a delay, working memory will be cleared out and people will depend more on long-term memory and judge their future performance more accurately. In one study (Dunlosky & Nelson, 1994), people learned a set of words either through rote rehearsal or by forming mental images. As discussed in Chapter 3, memory is better when people use imagery. As shown in Figure 15.1, when people made

JOLs immediately after studying there was little to no distinction made between how well they thought they had learned in the different conditions. However, with a delay, the difference between the JOLs in these conditions was the same as what is revealed by actual memory performance.

These JOL improvements are consistent with Koriat's (1993) accessibility hypothesis. The low correspondence between immediate JOLs and later memory may be due to the mismatch between conditions when a person is studying (when the information is present) and those at test (when the information is absent), making it difficult to predict future performance (Koriat & Bjork, 2006). Specifically, JOLs are more accurate the closer the conditions at the time the judgments were made to those when memory retrieval occurred. When people can properly assess what is available in long-term memory and the strength of their information sources, JOL estimates are more accurate.

Koriat (1997) outlines how JOLs are affected by three types of cues that are available to people: extrinsic, intrinsic, and mnemonic. **Extrinsic cues** are aspects of the learning situation, such as massed or distributed practice, or presentation times. People are not attuned to how these influence learning and JOLs are generally not affected by extrinsic cues. **Intrinsic cues** are aspects of the material being learned, such as the perceived ease of learning. In contrast to extrinsic cues, JOLs are sensitive to intrinsic cues. This is in line with the cue familiarity hypothesis. Finally, **mnemonic cues** are memory-based sources of information. These are assessments of how people have done on previous judgments. Over time, with practice, if people continue to make JOLs they tend to shift from using intrinsic cues to using mnemonic cues (Ariel & Dunlosky, 2011). This is in line with the accessibility hypothesis.

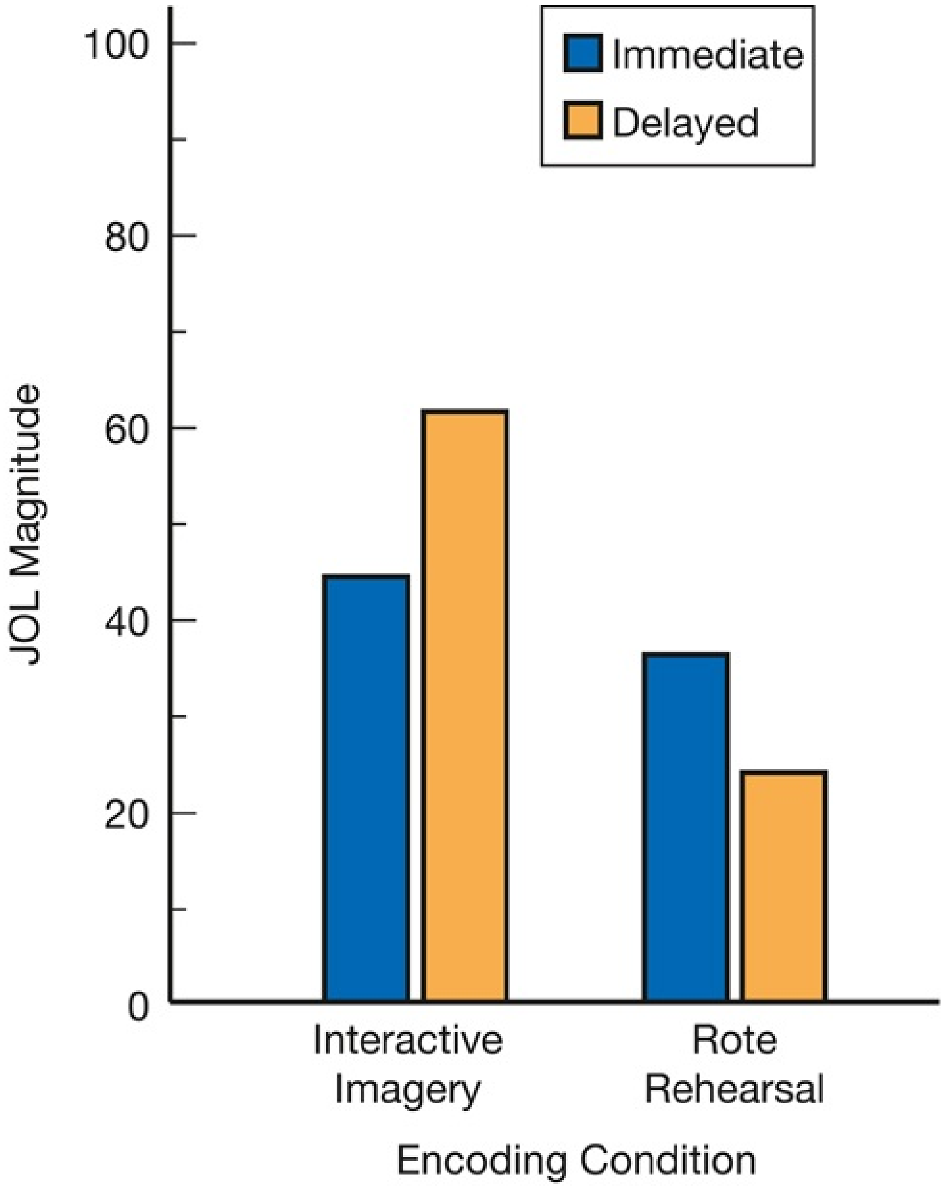

FIGURE 15.1 *Judgments of Learning: Words Were Learned Under Imagery or Rote Memorization Instructions, Given Either Immediately or After a Delay*

Adapted from: Dunlosky, J., & Nelson, T. O. (1994). Does the sensitivity of judgments of learning (JOLs) to the effects of various activities depend on when the JOLs occur? *Journal of Memory and Language, 33*, 545–565

Additional information does not always improve JOLs. In some cases, JOLs can actually worsen with additional information. For example, multiple study-test cycles can worsen JOLs over time (Koriat, 2002). Declines in JOLs also occur when there is competition among memory traces. For the fan effect (see Chapter 8), retrieval is more difficult with an increased number of associations with a concept. This also lowers JOLs (McGuire & Maki, 2001). When additional memory traces compete with a desired memory trace, people judge that they do not know the information so JOL estimates are worsened. This is in line with the competition hypothesis. Finally, sources of information that are completely extraneous and irrelevant to whether material has been learned can intrude on the JOLs. Alban and Kelley (2013) found that people gave higher JOLs if they were holding a heavier rather than a lighter clipboard when they made their judgments. Presumably the extra effort of holding the heavier clipboard got translated into greater effort spent learning, and so increased JOLs.

Although JOLs can be inaccurate, people do have some sense of their own learning. These JOLs impact the **allocation of study time** (Metcalfe & Finn, 2008a). Ideally, study time should maximize the amount of new knowledge that is learned. Spending all your time on material you already know well is less effective. It may increase overlearning but it does not help you learn new things.

Although people can allocate study time based on some particular goal to learn certain items over others (Ariel, Dunlosky, & Bailey, 2009), in general they regulate study time based on how easy they think pieces of information are to learn. However, this allocation is not always optimal or effective. People may choose distributed practice for easy items and massed practice for difficult items, which is ineffective (Son, 2004; but see Benjamin & Bird, 2006). When people first encounter information, they tend to focus more effort on the difficult items, often using massed practice (which also gives the illusion of harder studying). Moreover, because these items are so difficult, people have trouble learning anything new. They spend most of their effort on things that are far from being learned. As a result, there is little gain of new knowledge. This is the **labor-in-vain effect** (Nelson & Leonesio, 1988).

Improving Your Memory

One of the primary reasons that people want to improve their memories is to make it easier for them to learn new things. This is particularly true for things that people learn in school. As is illustrated in this portion of the chapter, we are sometimes not very good at knowing when we've learned something well enough. So, what can you do to improve this? Well, first off, as you are studying, write down a list of topics and questions that cover the material that you are studying. After you've read through and studied the material, set it aside and do something else for a while. Then come back to your list and see which of those topics and questions you can retrieve from memory. If you can do retrieve them, then it is more likely that you've learned that material. If not, then you can better target your study time later.

Because you are only testing your self on the material you initially determined to be important, this opens up the possibility that there can still be gaps in your knowledge. This is why you should try to find time to study with your classmates, quiz each other, and find out what you may have missed. Other people remember and think about the material differently from you, and interacting with them allows you to more completely learn the material in a shorter amount of time than if you simply work by yourself. As always, be sure to begin with the material that overlaps the most with what you already know and work your way out to the more difficult material. This way you won't waste as much of your study time.

However, the picture is not completely dismal. As people gain experience with the new material, study time allocation becomes more effective. People shift to spending more time on material that is just beyond their current ability level. This is called the **region of proximal learning** (Metcalfe, 2002, 2009). This method is more efficient because people spend less time on knowledge that is well beyond their ability. Instead, they focus on things that can help them ratchet up to the next level.

As mentioned in Chapter 7, memory can be boosted if people take a test after studying as compared to simply studying some more. This is the testing effect. Another reason that the testing effect helps overall learning is that, after testing, people are better able to distribute their study time as they now have explicit knowledge of what they do and do not know (Soderstrom & Bjork, 2014). Overall, people do have some awareness of their own learning. They do better when they can pace their own learning rather than follow along at a set pace (Markant, DuBrow, Davachi, & Gureckis, 2014).

Feeling of Knowing

When you forget things, it does not always feel the same. Sometimes you don't know something and it seems like you never learned it. Other times, you don't know the answer but you feel that it is somewhere in memory and, if you heard or saw it, you would be able to identify it. These forgetting differences are revealed by **feeling-of-knowing**, or **FOK**, judgments (Hart, 1965).

To acquire FOK judgments, people are asked a series of moderately difficult questions, such as, "who was Richard Nixon's vice president before Gerald

Ford?” Some things were never learned, but others were learned but are no longer prominent. After failing to recall an answer, people make an FOK judgment by rating how likely it was that they would identify the answer on a later recognition test. Then, at the end, people are given a recognition test to see how well their FOK judgments corresponded to actual memory. In general, FOK judgments are reasonable predictors of future memory, although there are some deviations.

Although FOK judgments can be reasonably accurate, there is some inaccuracy. For the cue familiarity hypothesis (Reder, 1987), FOK judgments are based on the familiarity of the information in the question or cue. One way to test this is by using the “game show” method (Reder, 1987), in which people are given a question and then either answer it (control condition) or indicate that they know the answer (game show condition). This is called the game show method because it is like a game show in which the contestants are asked a question and the one who hits the buzzer first gets to answer. This technique reveals that people know whether they have information in memory before they can actually retrieve it, as shown in Figure 15.2. Moreover, the rate at which people indicate that they know an answer is related to the familiarity of the information in the question and not necessarily what is in memory (Reder & Ritter, 1992). Similarly, people give higher FOK ratings to things they think they ought to know, rather than what they actually know (Costermans, Lories, & Ansay, 1992). In general, FOK involves a controlled assessment of memory as people with frontal lobe damage are much less accurate on FOK tasks (Janowski, Shimamura, & Squire, 1989).

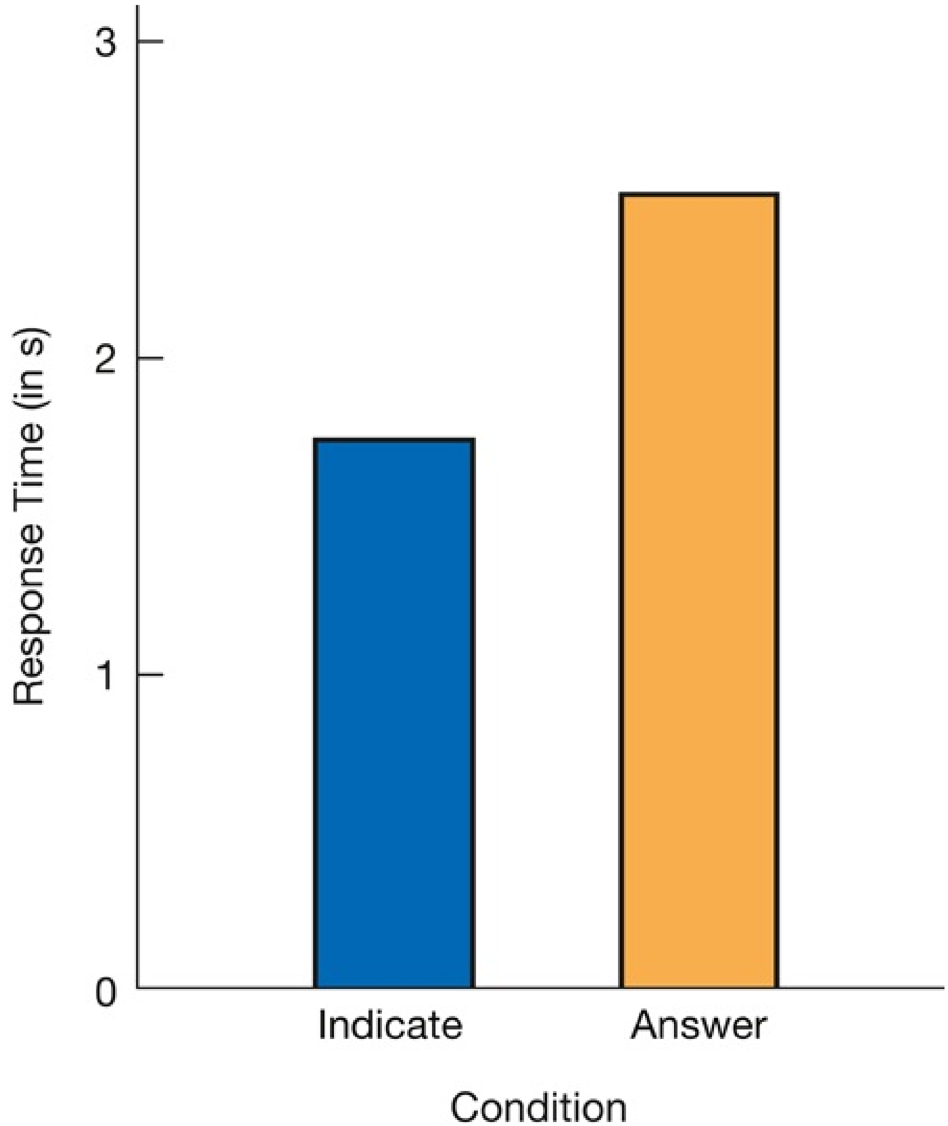

FIGURE 15.2 *Difference in Response Times: People Either Had to Answer a Question (Control) or Indicate That They Knew the Answer (Game Show)*

Adapted from: Reder, L. M. (1987). Strategy selection in question answering. *Cognitive Psychology*, *19*, 90–138

FOK judgments are related to how much partial information is retrieved (Koriat, 1993, 1995). Most of this partial information is semantic attributes of what people are trying to remember (Koriat, Levy-Sadot, Edry, & de Marcas, 2003), such as failing to recall a name but knowing that the person was a nineteenth-century composer who lived in Germany. However, metamemory judgments can be tricked in some cases. For example, FOK increases when information is revealed slowly rather than presented all at once, showing a revelation effect (see Chapter 13) on metamemory judgments (Young, Peynircioğlu, & Hohman, 2009). With a large amount of accurate partial information, there is a high correspondence between FOK ratings and future memory. However, if the partial information is incorrect, the correspondence is lower. This is why the overall relation between FOK ratings and actual memory is not ideal.

Partial information also predicts whether what is eventually retrieved is “remembered” or is just “known” (Hicks & Marsh, 2002; see the remember–know section later in this chapter). A cue familiarity account applies more to the early stages of the processing, which are related to “known” information. However, an accessibility account applies more to later stages, when familiarity with the cue is high and people have gone past the initial evaluation stage (Koriat & Levy-Sadot, 2001), which is related to “remembered” information. Finally, FOK judgments are affected by the number of competitors involved. If people are trying to remember something, FOK ratings are higher if that memory has a smaller set of competitors (Schreiber, 1998). This is in line with the competition hypothesis.

Tip-of-the-Tongue State

A **tip-of-the-tongue (TOT) state** is when people fail to recall information but feel that they are about to retrieve it. It is on the tip of their tongues (Brown & McNeill, 1966).[1] This seems like a FOK judgment. However, a FOK judgment assesses whether people think the information can be remembered, whereas a TOT state indicates that remembering is imminent (Brown, 1991; Schwartz, 2001). Also, FOK and TOT judgments are differentially affected by a working memory load (e.g., remembering sets of digits), with FOK judgments increasing or unaffected, but, as the load increases, TOT rates decrease (Schwartz, 2008). With a higher working memory load, it is harder to evaluate partial information that is being retrieved for FOK judgments. However, TOT rates are lower because less partial information is retrieved because it is being blocked by the information that is being actively maintained as part of the dual task.

There are a number of characteristics of TOT states that have been identified (Brown, 1991). First, people experience them on average about once a week. Second, there is often some information available. People can typically think of words that are similar to the one that is needed, in terms of meaning, sound, or both. Also, people may be aware of the first letter of a word or the number of syllables that the word has (Brown, Burrows, & Caderao, 2013). Third, people in a TOT state often have trouble with proper nouns, such as names. Fourth, people in a TOT state may be aware of the first letter or sound of the word, and perhaps the last one as well, along with the number of syllables. Finally, the occurrence of TOT states is not related to current feelings of stress or anxiety, although people are more likely to be in a TOT state, as opposed to simply forgetting, if the information is emotional (Schwartz, 2010).

One theory of the TOT state is the **incomplete activation view** (Brown & McNeill, 1966). A TOT state occurs when the search range has not been suffi ciently narrowed. There are too many possibilities, so people cannot retrieve the desired word. Another theory is a **blocking view**, in which TOT states occur when related but inappropriate competitors are activated to a greater degree and block access to the appropriate information. These blocking memories make it harder to access the target memory. Because these wrong traces have been retrieved recently, they are more available and so are more likely to be retrieved again. People keep retrieving the wrong memory. This starts a vicious cycle, resulting in the TOT state. After a period of time, if you stop trying to retrieve the memory, the activation level of the blocking trace(s) goes down, and it becomes easier to access the information you had so much trouble getting at before.

Knowing That You Don't Know

Sometimes we feel like we know something, even if we can't remember just what it is at the moment. Other times, we know that we just don't know something. No matter how long we search, the information can never be remembered. For example, if I asked you the question "when was the city of Lakewood, Ohio, founded?" "is scissel a word?" or "does President Obama use an electric toothbrush?" most of you know immediately that you do not know the answer. What is interesting about these **don't know judgments** is that people make them as rapidly as they do about knowledge that is actually in memory, if not more rapidly (Kolers & Palef, 1976). Why does this occur?

Feeling that you don't know something is different from feeling that you do know something (Liu, Su, Xu, & Chan, 2007). When people are asked about very unfamiliar topics, they can rapidly make a judgment based on the information in the question, which consistent with the cue familiarity hypothesis (Reder, 1987). For a question with very unfamiliar information, because the process of memory retrieval does not get very far, people can quickly identify the information as unknown.

In support of this, in a study by Glucksberg and McCloskey (1981), people first explicitly learned that they did not know certain pieces of information, such as "it is unknown whether John has a pencil" (*explicit don't know*) along with items that were known, such as “John has a shovel” (*true*) and “John does not have a chair” (*false*). After learning, people made “yes,” “no,” and “don’t know” responses to these items, as well as to new items that they would not have known about. People were slower and less accurate in saying that they did not know something if they had previously learned that they did not know it than if they had never studied it (see Figure 15.3). Thus, by having something in memory for the “don’t know” facts that were learned, there is now something in memory to access, and so retrieval time slows down accordingly. However, when nothing was learned, there is nothing in memory, so rapid “don’t know” responses are made. “Don’t know” responses are faster when there is no relevant information in memory but they are hindered when there is relevant information in memory, even when this is knowledge that the information is not known.

When asked questions about things people don’t have in memory, if the information is distinctive it will not make contact with many memory traces. This is a failure to retrieve any information in a very short period of time. Based on this lack of retrieval, people can judge that the information is not known (Ghetti, 2003). This is consistent with the accessibility hypothesis.

Stop and Review

Judgments of learning are important for effective studying. Unfortunately, the relationship between JOLs and later accuracy is often low. Part of this is because people make JOLs before clearing out what is left in working memory. People use their JOLs to manage their study time in inefficient ways and may spend too much effort on material that is too difficult, thus laboring in vain. With more experience, people learn to use what is already known as a springboard for learning new things. When people forget something, they can estimate whether they know it, even if it is not currently available, as with feeling-of-knowing judgments. These are based on either partial information or an assessment of the familiarity of a cue. When remembering seems imminent, it is a tip-of-the-tongue, or TOT, state. Finally, when there is no information in memory, people can quickly say that they do not know something.

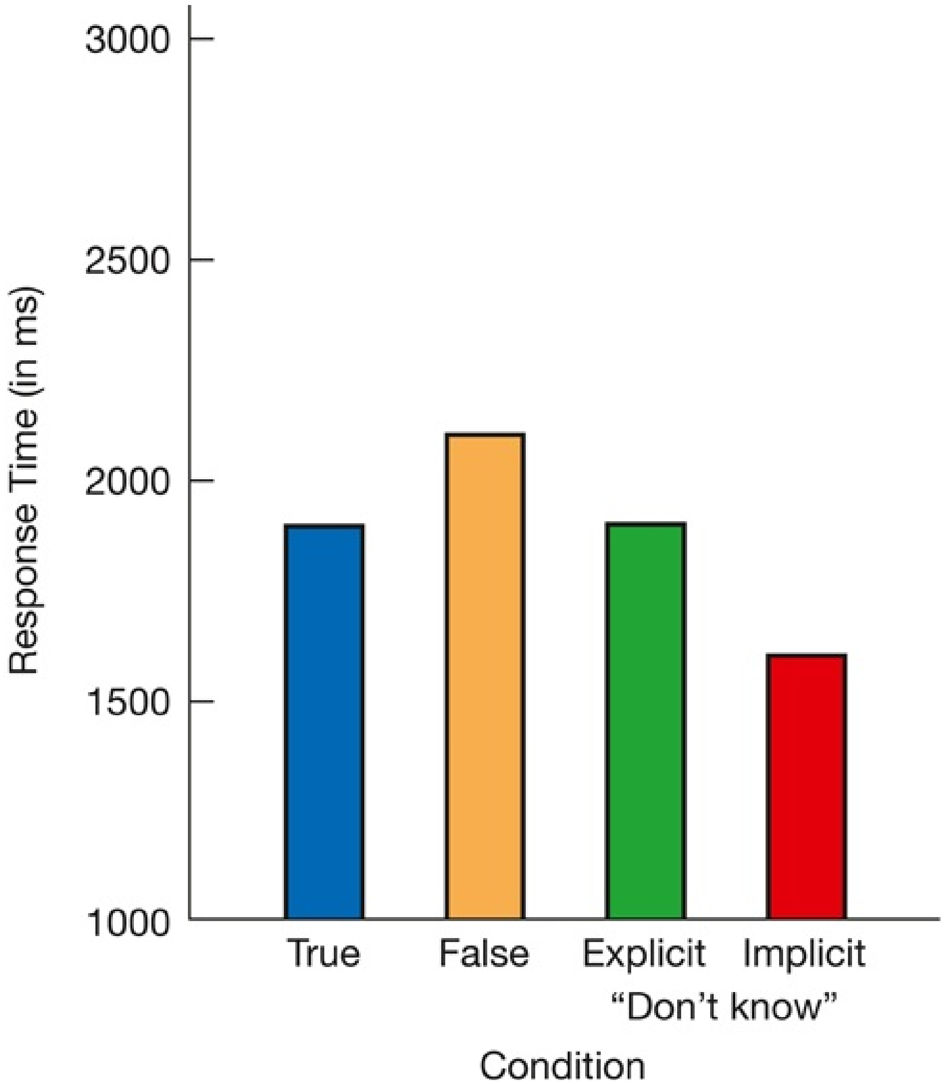

FIGURE 15.3 *Difference in Response Times: Questions were True, False, or Unknown—"Don't Know" Responses Were for Facts That Were Either Learned Earlier as "Don't Know" (Explicit) or Not (Implicit)*

Source: Glucksberg, S., & McCloskey, M. (1981). Decisions about ignorance: knowing that you don't know. *Journal of Experimental Psychology: Human Learning & Memory*, *7*, 311–325

MEMORY PHENOMENOLOGY

In this section we look at the phenomenology or conscious experience of remembering. We first look at the difference between conscious and unconscious memories as outlined by the remember–know distinction. Then we cover how errors in recollection lead us to misunderstand what we were like in the past, as with the hindsight bias.

Remember Versus Know

Up to this point we have been talking about metamemory judgments for information that a person either does or does not remember. Now, let's consider cases where people rate the quality of what they do remember by making a **remember–know judgment** (Gardiner, 1988; Tulving, 1985). If the remembering experience is accompanied by a conscious recollection of the circumstances in which the information was learned, this is a "remember" experience.[2] In contrast, if people do not consciously recollect but only have a feeling of familiarity, this is a "know" experience.

A great deal of research has been done on the remember–know distinction (Gardiner & Java, 1990, 1991; Gardiner & Parkin, 1990; Gardiner & Richardson-Klavehn, 2000). It appears that "remember" and "know" responses reflect relatively independent qualities of memory (Dudukovic & Knowlton, 2006). Research has shown a double dissociation between these types of responses. That is, things that affect one type of response do not affect the other and vice versa. Thus, remembering and knowing capture different ways of using memory.

"Remember," but not "know," responses are affected by elaborative rehearsal, generation effects, frequency of occurrence, divided attention at learning, the retention interval (if less than a day), reading silently or aloud, intentional versus incidental learning, serial position, and external context (Gruppuso, Lindsay, & Masson, 2007). As an example, if you read something aloud you are more likely to have a "remember" experience than if you read it silently. However, the probability of giving a "know" judgment would be the same, regardless of how you read the text.

In contrast, "know," but not "remember," responses are affected by the amount of maintenance rehearsal, repetition priming, stimulus modality (e.g., visual or auditory), and suppression of focal attention. For example, if you engage in maintenance rehearsal and repeat a word over and over, this does not alter the degree that you later recollect it. However, if you did happen to remember it, you would be more likely to say that you "know" that you learned it.

There are cases where "remember" and "know" responses are both affected but in opposite ways. Cases of this type are word versus nonword memory, massed versus distributed practice, gradual versus abrupt presentations, and learning in a way that emphasizes similarities or differences (Cook, Marsh, & Hicks, 2006). For example, with massed practice, "remember" responses are less likely and "know" response are more likely. In other cases, "remember" and "know" responses are similarly affected, such as by the retention interval (if more than a day), the amount of unfamiliar information, and long versus short response deadlines (when people are forced to respond within a certain period of time).

This distinction between "remember" and "know" metamemory responses corresponds to differences in memory quality or kind. For example, "remember" responses correspond to knowledge-based, conceptually driven processing, and "know" responses correspond to perceptually based, data-driven processing (Rajaram, 1993). This distinction is also supported neurologically. For example, relative to "know" responses, "remember" responses involve greater parietal lobe involvement (Curran, 2000), greater EEG activity (Burgess & Ali, 2002), and more hippocampus activity, whereas "know" responses reflect more parahippocampus activity (Meeter, Myers, & Gluck, 2005).

This distinction between "remember" and "know" responses reveals differences between expert's and novice's memories. The influence of prior knowledge, such as schemas, on retrieval is often observed with recall but less frequently with recognition. Experts almost always recall more accurately than novices, but these two groups do not differ on recognition tests. This is related to the fact that experts are more likely to give "remember" reports, whereas novices are more likely to just say that they "know" it. Long and Prat (2002), in a study of students at the University of California, Davis, had students read stories based on the television series Star Trek. Some of the students were experts (people who watch the show a lot) and some were novices (people who watched the show only occasionally). The two groups performed similarly on a recognition test of the stories. However, the experts were more likely to report that they remembered reading the items, whereas the novices were more likely to say that they knew them. The experts' prior knowledge allowed them to spend more time making inferences and elaborating on the memories they were creating, which made it more likely that they would have an experience of remembering it.

Recognition Without Awareness

The difference between "remember" and "know" responses reflects differences in conscious and unconscious experience, explicit and implicit memory, and direct and indirect memory assessment. Thus, our metamemory abilities are limited. There are many memory processes that occur beyond our awareness. This is even true for things that it seems as though we should be able to have conscious awareness of but do not.

A simple form of memory retrieval is recognition. Something is encountered in the environment and people either recognize it as having been encountered before or not. This awareness of the "pastness" should seemingly be conscious, even if people cannot explicitly say when or where in the past something was encountered. However, **recognition without awareness** occurs, in which people recognize things that they've seen before without any conscious awareness that they have done so (Peynircioğlu, 1990). People feel like these recognition judgments feel like they are being made at chance.

As one example of recognition without awareness, Voss, Baym, and Paller (2008) showed people series of kaleidoscope images. Then, people were asked to select the images that they had seen earlier from a set of old and new images. Although people felt like they were making guesses as to which they saw before, performance was well above chance. Thus, people recognized previously seen items, even though they had no conscious awareness of doing so. This unconscious recognition is accompanied by identifiable changes in ERP signals 200–400 ms after the pre sentation of a test image (Voss & Paller, 2006). This phenomenon is regularly observed with a variety of stimuli, including line drawings (Cleary, Langley, & Seiler, 2004), faces (Cleary & Specker, 2007), scenes (Cleary & Reyes, 2009), spoken words (Cleary, Winfield, & Kostic, 2007), songs (Kostic & Cleary, 2009), and odors (Cleary, Konkel, Nomi, & McCabe, 2010).

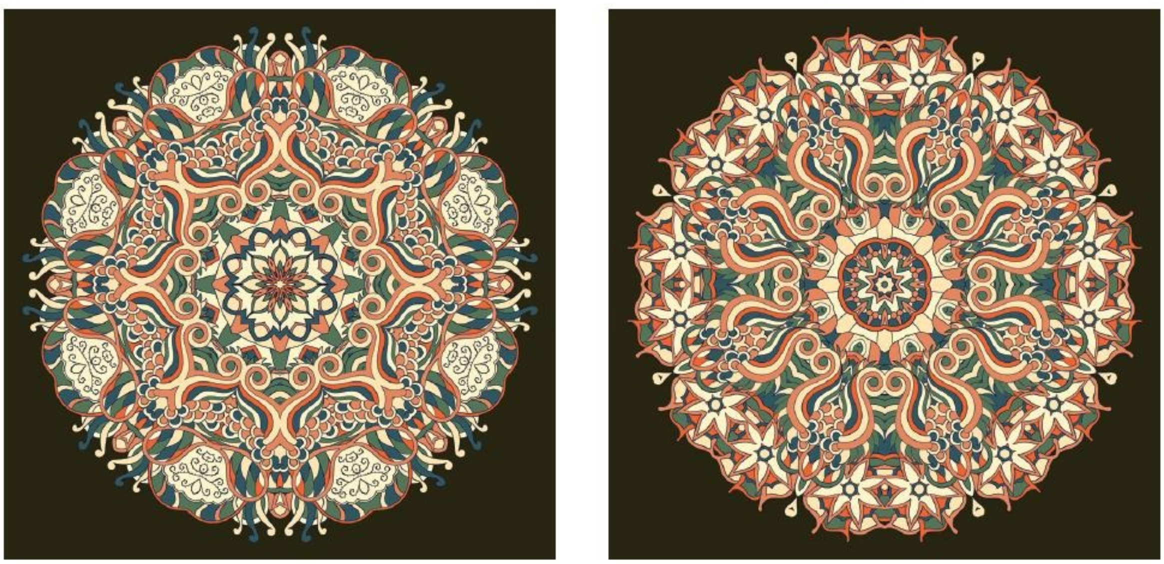

PHOTO 15.1 *Examples of kaleidoscope images similar to the ones used to assess recognition without awareness*

Source: geliostrk/iStock/Thinkstock

Craik, Rose, and Gopie (2015) suggested that recognition without awareness occurs as a result of two factors. First, the knowledge of items or events must first be encoded into memory. If not, then there can be no recognition because the information is not in memory to begin with. The second requirement is that information about context is weak or absent. Thus, people would have no feeling that something was experienced in the past.

Hindsight Bias

People tend to think of events as being more deterministic after they happen than they thought those events would be before they occurred. This is the **hindsight bias** and this increased deterministic thought after the fact is called “creeping determinism” (Fischhoff, 1975). For memory, the hindsight bias is seen when people remember their mental state as being different from what it really was. People misremember their memory as being more similar to their current knowledge state.

As an illustration of this, in a study by Safer, Bonanno, and Field (2001), bereaved spouses rated their grief six months after the death and then four and a half years later. At the second rating, people also rated how much grief they felt at the six-month period. Although most people said they felt more grief at the six-month period than they currently did, their memory of their experience was positively related to their current level of grief. Thus, they misremembered their emotional states in hindsight based on their current state.

The hindsight bias pervades many aspects of life. Other examples of this effect are memories for people’s predictions of outcomes of the Rodney King civil rights trial (Gilbertson, Dietrich, Olson, & Guenther, 1994), the Clarence Thomas Supreme Court Justice confirmation vote (Dietrich & Olson, 1993), memory for the probability of a medical diagnosis being correct (Arkes, Wortman, Saville, & Harkness, 1981), the results of political elections (Blank, Fischer, & Erdfelder, 2003), the outcome of sporting events (Leary, 1981), the inevitability of a work layoff (Mark & Mellor, 1991), and memory for faces (Harley, Carlsen, & Loftus, 2004). This reinforces the point that our memories are in a constant state of flux and what we currently remember is in part due to our experiences and current state.

The hindsight bias also applies to romantic relationships. People’s memories of their relationships are biased in the direction of their current opinion of the relation ship. People who are happy with their relationship remember events more positively than people who are unhappy (McFarland & Ross, 1987). Moreover, even when relationship satisfaction is constant, people misremember the relationship as improv ing over time (Sprecher, 1999). This leads to an unusual idea that people in satisfactory relationships, even for marriages of over 20 years, are biased to remember the past as being worse than it really was, although they remember the relationship positively overall. This bias is a trick that makes the relationship seem as though it is improving more than it actually is (Karney & Coombs, 2000). So, as a result, people have a more positive attitude toward their relationship than if memory were accurate.

The hindsight bias is driven by a need to reconcile one's current view with memory for the past. For example, people show a larger hindsight bias when outcome information is surprising than if it is more congruent with what one knows (Ash, 2009). The idea is that the act of trying to make sense of a surprising outcome leads people to think more about the information, reconciling it with what is already known, thereby leading to the false impression that the information was better known than it actually was.

A major variant of the hindsight bias is the **knew-it-all-along effect** (Wood, 1978). In studies of this phenomenon people are asked to evaluate information in some way at stage 1—for example, judging whether a series of statements are true or false, such as that "Lhasa is the capital of Nepal." Then, at stage 2, people are given feedback about the information encountered at stage 1, such as learning that Kathmandu is the capital of Nepal. This feedback is likely to be knowledge that the person did not have at stage 1. Finally, in stage 3, people indicate their memory for what they knew at stage 1. Compared to people who got no feedback at stage 2, metamemory reports of prior knowledge are biased toward the information learned during stage 2. After stage 2, people have a hard time remembering what it was like not knowing something, as if they knew it all along.

The knew-it-all-along effect can be reversed if the more recent learning is discredited in some way. For example, if you didn't know the capital of Nepal originally, were then told the capital name, you might show a knew-it-all-along effect and state that you knew this information before. However, if you were then told that the stage 2 information was wrong, this would reverse the bias to say that the information was known all along and there would be a more accurate assessment of what was and was not known (Erdfelder & Bechner, 1998).

In general, it is difficult for us to remember what it was like when we did not know something. College professors are no exception. If you have ever felt that one of your instructors was talking over your head, it may not necessarily be because he or she was arrogant or uncaring. The problem may have been that, because of the knew-it-all-along effect, he or she was having trouble remembering what it was like to learn the course material for the first time.

Another illustration of the hindsight bias is memory for remembering and forgetting. How well do people remember whether they had remembered or forgot something previously? Joslyn, Loftus, McNoughton, and Powers (2001) tested people one day and six weeks after learning something. At the six-week session, people were also asked whether they had remembered or forgotten specific items at the first session. People were more accurate at remembering their previous memory successes than remembering their previous forgetting. About half the time that people had originally forgotten something, it was later reported that it had been remembered. Thus, there is a metamemory bias to think that we have better memories than we do.

Memory can also be affected by our **beliefs** about memory. In a study by Winkielman and Schwartz (2001), some people were told that sad events fade faster from memory, whereas others were told that happy events fade faster. The people who were told that sad memories are forgotten faster were more likely to rate their childhood as less happy. It is as if people think that, if they have forgotten many sad memories, then their childhood must have been less happy than they would have otherwise rated it.

While current knowledge can influence memory of prior knowledge, it is not the case that people have completely lost the original information. If the current knowledge state is discredited in some way, people can disregard it and gain more accurate access to the original knowledge state. In a study by Hasher, Attig, and Alba (1981), Temple University students were first given a set of statements to rate as being either true or false. In a second stage, they were told that some of the items were either true or false. Importantly, at the third stage, some of the students were told that the information they were given in the second stage was incorrect. When the information from the second stage was discredited, people accurately remembered their original opinion in the first stage. In contrast, people who received no discrediting feedback showed the standard knew-it-all-along effect. This reinforces the idea that our memories are using multiple sources of knowledge and that what we remember is the degree to which these different memory traces and processes are emphasized.

STUDY IN DEPTH

To better understand how beliefs and the hindsight bias can influence metamemory judgments, let's go over a study by Henkel and Mather (2007) on memory for choices. The aim of this study was to assess whether people's beliefs about their choices change their memories for what those choices were. Specifically, people tend to misremember the features of various options that they were given to be more consistent with their own choices.

This study involved testing 80 students at Fairfield University, who were asked to read through five scenarios in which they had to pick between two options. These scenarios involved making choices between roommates, summer internships, apartments, used cars, and potential dating partners. The order in which these scenarios was randomized for each participant.

For each scenario, each of two options had both positive and negative features and people were asked to pick which of these they would prefer. For example, for the used cars scenario there were 10 features for each car. Five of the features were positive and five were negative. The particular positive and negative features were randomly assigned to each choice. The options for two cars are listed below. People read through the descriptions at their own pace.

Car 1	*Car 2*
Hard to find service outlets	No warranty
Has a dent from a previous accident	Some rust on exterior
Seats are very comfortable	High resale value
Good handling on turns	Has airbags
High mileage on odometer	Needs a few repairs
Makes an unidentified rattling sound	Not much trunk space
Prestigious model	Powerful engine
Air conditioning included	Previous owner took good care of car
Does not do well in bad weather	Not fuel efficient
Stereo included	Has a sunroof

Two days later, the people returned to the lab and were given a memory test for the features for the options they had seen. For each scenario these memory tests were randomly ordered lists of the features of the two choices, along with some additional features that were not seen for either choice. People were told to indicate whether each feature belonged to their original choice, belonged to the other choice, or was a new feature.

What was found was that people were more likely to misremember the positive features as being for the choice they selected and the negative features for the choice they selected against. So, people have a memory bias to think that things that are consistent with their own beliefs have more positive and fewer negative characteristics than they actually do.

A similar reduction of the knew-it-all-along effect occurs if people are asked to retrieve only information that was recently learned, rather than what they remember knowing before the new knowledge (Begg, Robertson, Gruppuso, Anas, & Needham, 1996). Monitor source information helps people assess whether their knowledge is recent. Simply encouraging people to try harder has no influence. Finally, while asking people to consider alternatives is helpful, asking them to try to remember something, even after it becomes harder to think of other alternatives, may increase the potency of a hindsight bias. This happens because the additional retrieval attempts make the outcome seem more like it was already known (Sanna & Schwartz, 2004).

Stop and Review

Remembering is accompanied by different conscious experiences. "Remember" responses are associated with conscious recollection, whereas "know" responses are associated with unconscious feelings of familiarity. We are influenced by unconscious processes, even for basic direct memory tasks, such as recognition. This is recognition without awareness. Metamemory awareness sometimes leads people astray, as with the hindsight bias, in which we assess the past in a way that is more consistent with the present. Another example of this is the knew-it-all-along effect. Finally, our assessments of our own memories can be influence how we believe or understand our memories to work, even if these beliefs are inaccurate.

MNEMONICS

When we are aware of the limitations of our own learning and memory, we can take steps to address them. One thing we can do is to use metamemory techniques, known as mnemonics. **Mnemonics** are mental or physical devices used to help people remember. In some cases, the mnemonics involve the application of principles of memory that we have already discussed and that we know improve memory, such as the use of mental imagery (Morris, Jones, & Hampson, 1978). Of course, the use of multiple strategies together provides a larger boost to memory (Morris, Fritz, Jackson, Nichol, & Roberts, 2005).

There are a number of ready-made mnemonic devices that can be used as structured cue sets to help remember larger sets of information. One example is the **peg-word mnemonic**, in which people use a known sequence of items, or "pegs," on which to "hang" other pieces of information. For example, people might memorize the sequence “one is a bun, two is a shoe, three is a tree (and so on).” This structure can then be used as a set of pegs for other information. For example, suppose you needed to go to the grocery store to buy onions, milk, and watermelon. You could use the peg-word mnemonic by forming a mental image of sliced onions on a bun, a shoe full of milk, and watermelons hanging from a tree. When you get to the store, your sequence of pegs will help you remember the images you formed, which will help you remember what you need to buy. Part of the reason the peg-word mnemonic works (as well as the method of loci, described next) is that there is an encouragement by the mnemonic to form and use mental images (Wang & Thomas, 2000).

Another common mnemonic is the **method of loci**. For this mnemonic, people first have a set of well-known locations, such as rooms in a house, locations along a familiar path, and so on. A more linear path (e.g., a route to work) can be more effective in remembering a sequence than a set of locations with no clear linear ordering (e.g., the rooms of a house), in which multiple orders are possible (Massen, Vaterrodt-Plünnecke, Krings, & Hilbig, 2009). People then imagine things at each location. To use our grocery shopping example, people might mentally place the onions in the living room, cartons of milk at the foot of the stairs, and watermelons in the dining room. Then, to remember, people take a little mental tour of their home.

A concern might be that, for the method of loci, people would need a new set of locations each time one wants to learn something. Otherwise, proactive interference builds up (see Chapter 8) and the effectiveness of a given set of locations decreases over time. While proactive interference occurs, it is not the repeated use of the same collection of spatial locations that produces the interference but any overlap in the content of the material (De Beni & Cornoldi, 1988; Massen & Vaterrodt-Plünnecke, 2006). Repeated use of the same locations as part of the method of loci does not create additional proactive interference. There is something about spatial locations that allows them to be used over and over with less retrieval interference than is experienced with other types of concepts.

Other mnemonics take advantage of the information itself. A **rhyming mnemonic** takes all the information and forms a rhyme from it. For example, “thirty days hath September, April, June, and November” is a rhyming mnemonic for the number of days in the months. **Acronyms** are a mnemonic in which the first letters of phrase are used to help people remember. For example, the word HOMES is an acronym for the names of the five Great Lakes: Huron, Ontario, Michigan, Erie, and Superior. Finally, **acrostics** are a mnemonic in which the first letters of the items are used as the basis of forming some new memorable phrase. For example, the phrase “on old Olympus’ towering top, a Finn and German vault and hop” can be used to help a person remember the names of the 12 cranial nerves in their correct order: olfactory, optic, oculomotor, trochlear, trigemenal, abducens, facial, auditory, glossopharyngal, vagus, accessory, and hypoglossal. Remembering the phrase provides the cues to the appropriate names as well as preserving the correct sequence.

There are many mnemonics people can use. Sometimes a mnemonic is a simple cue, like tying a string around your finger or switching a wedding ring from one hand to the other, to remember to do something in the future (**prospective memory**). Other times, the structure of the mnemonic helps people remember the information itself, such as the knuckle mnemonic, which is another way of remembering how many days there are in each month (see Figure 15.4). Regardless of the specific mnemonic, in all cases the ability to cue memory is at work, in much the same way as the other sorts of cues we’ve talked about (see Chapter 7).

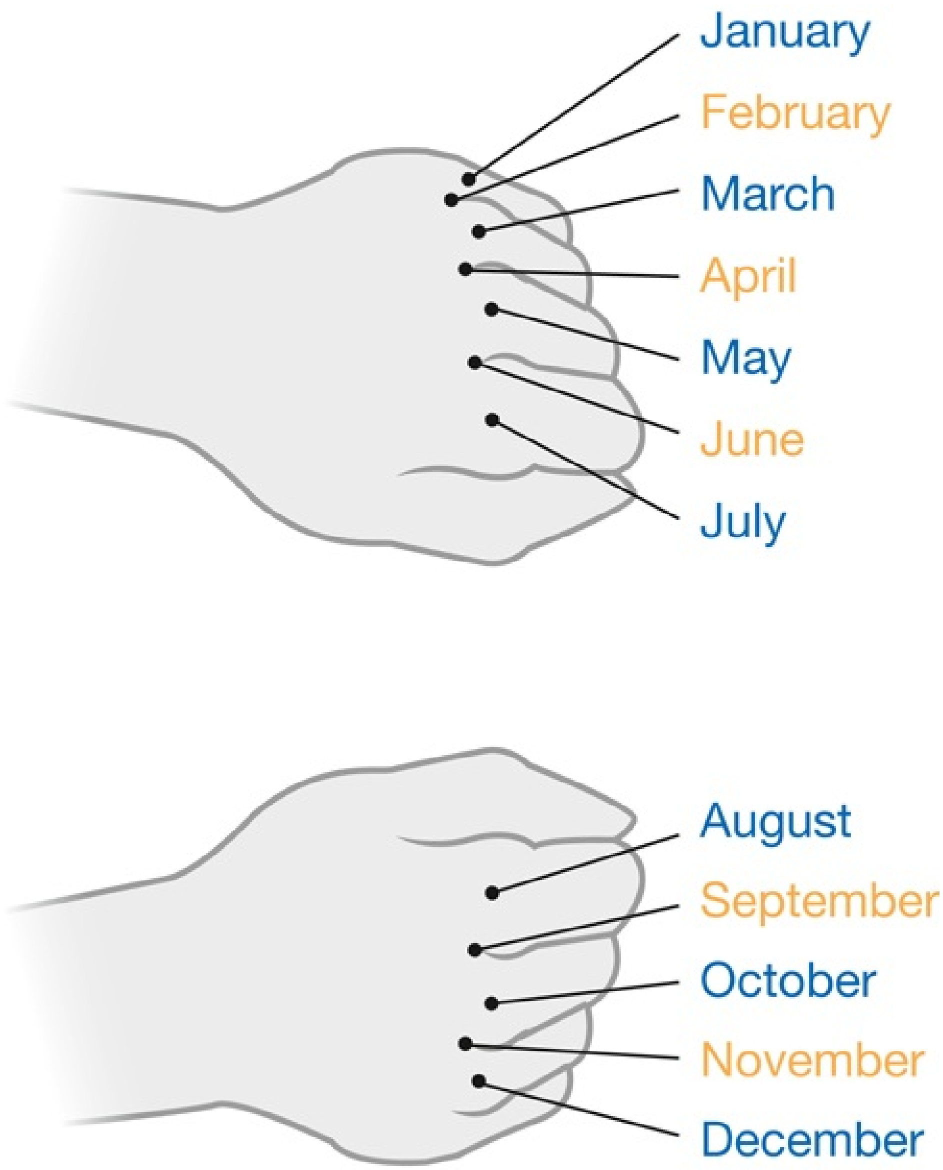

FIGURE 15.4 *The Knuckle Mnemonic*

These mnemonic techniques are useful to know and can be used to aid your memory. Some people use them as the initial basis for quickly learning large sets of information in memory competitions. The experience of participating in these memory competitions is narrated in a popular book by Joshua Foer (2011) called *Moonwalking with Einstein*.

As noted in Chapter 7, information can be represented in memory at different levels. In that chapter, it was noted that text memory we can identify three levels of representation: the surface form (verbatim memory), the textbase (memory for the ideas conveyed in a text), and the mental model (the situation described by the text). While the surface form and textbase levels are forgotten rapidly, memory at the mental model level is fairly stable, showing little to no forgetting (Kintsch, Welsch, Schmalhofer, & Zimny, 1990). The benefit of event cognition and narrative memory applies not only to memory for stories and situations you've encountered; it can be turned around. That is, you can use a **story mnemonic** to help you learn information that is not in a story form to begin with. As an example, Bower and Clark (1969) gave two groups of students 12 sets of 10 words each to learn in order. One group was simply told to learn the words and their order as best as possible. This was the control group. The other group was told to try to make up a story starting with the first word and going to the second. This was the narrative group. As shown in Figure 15.5, averaged across lists, people who created stories or narratives remembered the information much better. So, if you are looking for a way to better learn material that you are struggling with, try to make a story out of it.

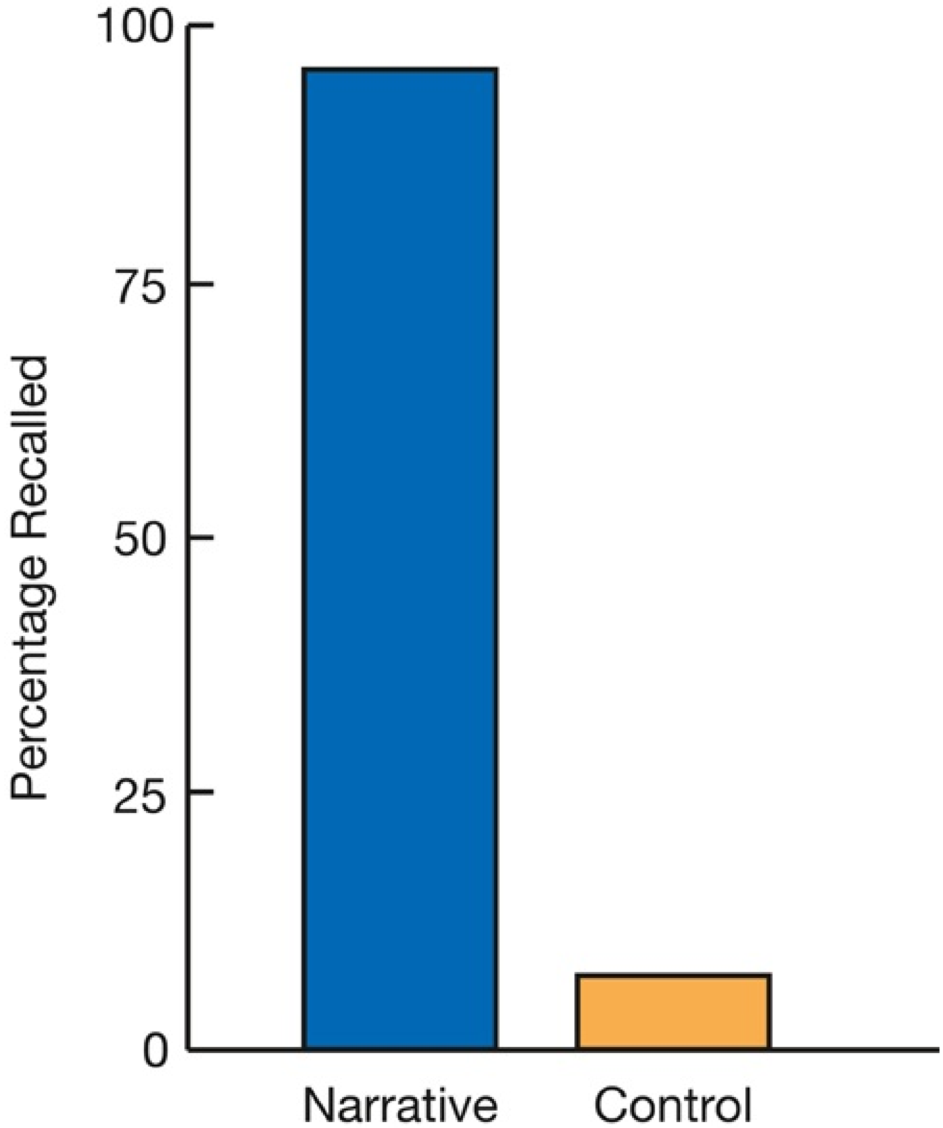

FIGURE 15.5 *Memory for Words as a Function of People Using a Story Mnemonic or Simply Trying to Remember as Effectively as They Can*

Derived from data reported in: Bower, G. H., & Clark, M. C. (1969). Narrative stories as mediators for serial learning. *Psychonomic Science*, *14*(4), 181–182

Stop and Review

People can use metamemory knowledge to help them remember better, as with mnemonics. Some mnemonics simply involve an application of memory-based principles. Others are more formal systems that rely on learning a new structure, as with the peg-word mnemonic. In comparison, other mnemonics use some well-known or readily available, consistent structure that can then be used as a guide, as with the method of loci. Other mnemonics use language structures, as with rhymes, acronyms, and acrostics. Mnemonics use any stable structure, including physical cues, such as a string tied around one's finger. Finally, the story mnemonic is an effective way of storing new information in memory.

TRY IT OUT

An important feature of metamemory is the ability to exert some control over your own learning and memory. For this Try It Out section we look at the use of mnemonics and mental imagery (Neath, 1998). Ideally you should have at least 16 participants in each of two groups.

First, create a list of 40 concrete nouns (things like dog, house, or rope, and not like truth, justice, or hope). Give your participants 20 random pairings of these words. Tell people that they will later need to be able to recall the second word when given the first word. For one group (the control group), simply tell them to memorize the word pairs as efficiently as possible. For the second group (the imagery group), tell them to try to form a mental image in their mind that involves the two objects interacting in some way (they don't need to tell you what their images are). Give people in both groups about five seconds per word pair during the study portion. Alternatively, you could use other mnemonics, such as the method of loci, the story mnemonic, or some other memory device, to see how these influence later memory.

At the end of the study portion, give people the first words of each pair and see if they can recall the second. You can do this by simply providing them a sheet of paper with the first words written in a column and have them write down the other work next to the appropriate first word. Total up and average the number of items remembered in each group. What you should find is that people who use imagery as a mnemonic should remember more of the words than the control group.

EXCEPTIONAL MEMORY

Having an awareness of one's own memory is helpful. Further improvements can occur as the range of knowledge is broadened. The more you know, the easier it is to remember because it is easier to organize and chunk information. Thus, expertise can cause people to have what would otherwise seem an exceptional memory for certain types of information.

We saw some of this in Chapter 4 with the case of S. F., a runner who extended his digit span to over 80 items (Ericsson, Chase, & Faloon, 1980). Another example is taxi drivers' memories for street names. Their superior memory is due to both the large amount of knowledge they have about streets in their city and the highly organized way this information is represented. For taxi drivers, information is chunked based on routes through the city (how they use this knowledge), rather than spatial proximity, semantic relatedness, or alphabetical order (Kalakoski & Saariluoma, 2001).

Other exceptional memories are cases when the knowledge people are using is implicit. Speakers of tonal languages, such as Mandarin Chinese and Vietnamese, are better at memory for musical pitches and are more likely to have perfect pitch than speakers of nontonal languages, such as English (Deutsch, 2002). Because those languages place a greater demand on remembering pitch information, this knowledge can then be applied, at an unconscious level, to memory for the pitches of tones used in music.

Memorists

People with exceptional memories are called **mnemonists** or **memorists**. We use the term memorist here because they are not necessarily relying on mnemonics as described previously (Neisser, 1982). A well-known memorist was Solomon V. Shereshevsky, better known as S., a man who lived in the Soviet Union in the early to mid-twentieth century (Luria, 1968). S. worked as a newspaper reporter in Moscow and had the uncanny ability to accurately remember large sets of details from an event without taking any notes. S. had a short-term memory span of over 70 items, with the additional amazing ability of recalling them in any order requested. He could also recall lists of items years after hearing them only once. It is also important to note that S. did not think that his memory was markedly better than anyone else's.

A major contributor to S.'s ability was the fact that he had synesthesia. This is a condition in which sensory qualities from different modalities intrude on one another. For example, different sounds may also be experienced as colors. S.'s synesthesia made his memory traces very rich and detailed, allowing them to endure, be highly structured in memory, and be recalled accurately later. While S.'s condition allowed him to remember exceptionally large sets of items, there were some drawbacks. For one, because he was so dependent on sensory and perceptual qualities, he found it difficult to comprehend and think about abstract ideas.

Not all memorists have an unusual neurological condition. There are a number of accounts of memorists and the techniques they use (Gordon, Valentine, & Wilding, 1984; Hunt & Love, 1972; 1983; Wilding & Valentine, 1997). To get an idea of how people become memorists, let's look at three, all of whom were in the *Guinness Book of World Records* for reciting pi from memory.

The first is Rajan Mahadevan (Biederman, Cooper, Fox, & Mahadevan, 1992; Thompson, Cowan, & Frieman, 1993; Thompson, Cowan, Frieman, Mahadevan, & Vogl, 1991) who set the record on July 5, 1981, by reciting pi out to 31,811 digits in 3 hours and 49 minutes. His memory ability was first observed at the age of five, when his parents hosted a dinner party for 50 people and he memorized, in just a few minutes, the license plate numbers of all of the guests' cars and then reported them back. Rajan has a letter span of 13, a visual digit span of 28, and an auditory digit span of 43. One strategy he uses is keeping track of the position of an item in a sequence, and he then uses this sequence to report information back. His exceptional memory is confined to digits and similar information. He sometimes extends his memorization approach to other types of information but not always with the same level of success. For example, when given a list of words, he is less likely to use semantic relations and his memory for stories and spatial information is in the normal range. Rajan also memorized information from a text or lectures. However, as many professors will tell you, while memorization is important, what is as important is the ability to apply and use that knowledge.

The second pi memorist is Hideaki Tomoyori, who set his record on March 9, 1987, by reciting pi out to 40,000 digits in 13 hours and 6 minutes (Takahashi, Shimizu, Saito, & Tomoyori, 2006). Tomoyori has good skills for memorizing long lists of numbers but his memory for word lists and stories is not exceptional. Tomoyori accomplished his task using a digit-symbol mnemonic in which the Japanese symbols for digits were combined to form words and then images. The digit-symbol mnemonic is like assigning letters to numbers in English (e.g., 1 = t, d, or th; 2 = n; 3 = m; etc.). Thus, his approach was very different from Rajan's. He also had a large, but not far from normal, digit span of 10 for auditory digits and eight for visual digits. His word and story memories were not different from standard controls. Thus, Tomoyori achieved his feat not through an innate talent but through the persistent application of a particular strategy and a lot of effort.

Tomoyori's record was bettered by the pi memorist Chao Lu, who, on November 20, 2005, recalled pi out to 67,890 digits in 24 hours and 4 minutes (Hu, Ericsson, Yang, & Lu, 2009). Lu did this by relying on the phonology, or word sounds, of the various digits to recode the information linguistically, much like Tomoyori, and then develop stories for himself out of this information.

However, he also developed techniques based on the shapes of the characters for the digits and their meanings. Lu has a normal digit span of about nine digits. Overall, these three memorists accomplished similar tasks using different talents and strategies.

Highly Superior Autobiographical Memory

So far we have discussed memorists who are using either synesthesia, or some mnemonic technique, such as the story mnemonic, to help them remember large amounts of information. Recent work suggests that there may be an exceedingly small set of individuals who have amazingly good memories for events of their lives. These people have what is called **highly superior autobiographical memory**. Studies into this condition started with a single case of a woman with the ability to remember nearly all of the events of her life from around the age of 14 onward (Parker, Cahill, & McGaugh, 2006). However, subsequent work has reported an additional 11 people who also have such good memory for their life events (LePort et al., 2012).

People with this condition not only have very good memory for the events of their lives and public events (e.g., a baseball game) but can also provide accurate information about the days and dates of those events. People with highly superior autobiographical memory remember the day of the week some event happened on, as well as what happened during a public or personal (autobiographical) event, at an accuracy level of about 80%, whereas most other people remember this information at a rate of about 10%. Thus, their event memory is stunningly good.

This storage, encoding, and retrieval of event memories appear to be done without any special effort. It occurs as a matter of course during the unfolding of their lives. These people are not using any mnemonic, such as calendar calculation, nor do they have any psychopathology, such as obsessive-compulsive disorder. Other than their highly superior autobiographical memory, they are normal. Many more people may have this condition and not realize it because their memories for events have always been very good and they may assume that other people have similar abilities. This superior memory ability is limited to events. It does not extend to memory for typical laboratory tasks, such as learning lists of words or digits.

Neuroimaging of the brains of these people shows some potential areas of differences from normal brains (although keep in mind that the number of such people to date is still quite small). This has been done using fMRI, as well as diffusion tensor imaging. These analyses suggest that there are neurological differences in the inferior and middle temporal gyri and temporal pole (BAs 20, 21, and 38, respectively), the anterior insula, and the parahippocampal gyrus (BA 36). Thus, their event memory skill may be due to underlying neurological differences and not how they've trained themselves to use their memories.

Eidetic Imagery

Some people think they have photographic memories, which is the ability to use mental images in a way that closely resembles perceptually viewing an image. This is called **eidetic imagery** (Gray & Gummerman, 1975). Someone with this ability would have an extraordinary memory for things seen earlier, showing little to no distortion. In general, there is little support for the existence of eidetic imagery. For the most part, people who report having eidetic imagery are instead using other memory skills to a high degree, often restricted to a limited range of knowledge.

Stop and Review

Some people have exceptional memories. In some cases, this comes with expertise and practice with mnemonics. Some memorists have memory skills that seem to defy the imagination but are limited to certain types of information. Other memorists have synesthesia that they can use to aid memory. Other people have highly superior autobiographical memory, in which they can remember events and dates from nearly all of their lives, well beyond the accuracy found with most people. Finally, despite claims to the contrary, there is little evidence to suggest that photographic memory exists.

PUTTING IT ALL TOGETHER

While most memories and memory processes are unconscious, there is a lot going on that is very conscious. This is the domain of metamemory, your awareness, monitoring, and control of your own memories. Metamemory is important for knowing what is in memory and how to remember. In terms of what is in memory, you can estimate whether you've learned something (and do so better if you wait for information to move out of working memory) and how to allocate your study time. During studying you may be tempted to spend too much time on difficult items, which is consistent with the labor-in-vain effect. However, over time you may drift more toward studying those items just beyond your current state of knowledge, in the region of proximal learning. Part of the problem with assessing the contents of your memory is that you are sometimes biased by what you know, as with the hindsight bias, and the knew-it-all-along effect.

For the issue of how to remember, it is clear that you use knowledge about both the questions you are asked (the cues), the answers that you know (the targets), and any trouble you have remembering (such as the competition from interference). Remembering and forgetting are associated with different subjective feelings. When something is forgotten, it feels different if you have some knowledge in memory (partial retrieval) than if you know absolutely nothing. There is also the distinct feeling that retrieval is imminent with the tip-of-the-tongue phenomenon. Moreover, it feels different to "remember" than to "know." The "remember" responses are related to conscious recollection, whereas the "know" responses are related to unconscious retrieval. This unconscious retrieval may even bring about recognition without awareness in which you recognize something without any conscious awareness of having encountered it before.

To get at the contents of your memories, you may use mnemonics that organize the storage and retrieval of material. Most of us are not memorists who are highly skilled with mnemonics, or have conditions such as synesthesia, or have highly superior autobiographical memory. But, if you do, you can exploit these to gain a better command over your memory. None of us has eidetic memories. Still, you can use what knowledge you have of your memory to improve how you use it.

STUDY QUESTIONS

1. What is metamemory? How does it differ from other kinds of memory?
2. What are the sources of information available to people when making metamemory judgments?
3. What are the major classes of theories of metamemory? How do they suggest that people use the different types of information that are available when making metamemory judgments?
4. How accurate are judgments of learning and how are they made? What can be done to improve judgments of learning?
5. What sort of cues are available to people when they are assessing whether they have learned something? Which are they more or less likely to use?
6. How effective are people at allocating their study time, and why? In what

ways are people ineffective? What are more effective ways to allocate study time?

7. What are feeling-of-knowing judgments? When are they given? How accurate are they?
8. What is the difference between feeling-of-knowing judgments and the tip-of-the-tongue state? What are some of the unique characteristics of the tip-of-the-tongue state? Why do they occur?
9. How do people assess that they do not know something?
10. What is the difference between "remember" and "know" responses? What evidence is there that these tap into different memory processes?
11. What is the recognition without awareness phenomenon and why does it occur?
12. What are the hindsight bias and the knew-it-all-along effects? How can they be avoided?
13. How do people's beliefs about how their memories work influence their ability to make judgments about their own memories?
14. What neurological structures are strongly associated with metamemory performance?
15. How do mnemonics work? What are some examples of mnemonics?
16. What are some of the ways that people can exhibit exceptional memory performance?

KEY TERMS

- accessibility hypothesis
- acronyms
- acrostics
- allocation of study time
- beliefs
- blocking view
- competition hypothesis
- cue familiarity hypothesis
- cues
- don't know judgments
- eidetic imagery
- extrinsic cues

- feeling-of-knowing (FOK)
- highly superior autobiographical memory
- hindsight bias
- inability hypothesis
- incomplete activation view
- intrinsic cues
- judgments of learning (JOLs)
- knew-it-all-along effect
- labor-in-vain effect
- memorists
- metamemory
- method of loci
- mnemonic cues
- mnemonics
- mnemonists
- monitoring-retrieval hypothesis
- peg-word mnemonic
- recognition without awareness
- region of proximal learning
- remember-know judgment
- rhyming mnemonic
- story mnemonic
- targets
- tip-of-the-tongue (TOT) state

EXPLORE MORE

Here are some additional readings so that you can further explore issues involving metamemory.

Brown, A. S. (1991). A review of the tip-of-the-tongue experience. *Psychological Bulletin*, *109*, 204–223.

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NOTES

1 See Thompson, Emmorey and Gollan (2005) for an account of a tip-of-the-fingers (TOF) state for deaf signers
2 Rubin, Schrauf, and Greenberg (2003) suggest that "remember" responses reflect a belief that an event occurred.

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CHAPTER 16

Memory in Infancy and Childhood

As we have seen repeatedly, memory is not stable and static. Our every experience alters our memories, making things easier or harder to remember, distorting some things and clarifying others. To further complicate this, people are in a constant state of development, changing from one age to another. These developmental changes can have profound implications for how memory functions. Early on in development, some memory processes are poorly functioning or absent, whereas others are in a nearly adult form. This chapter examines some of the major issues in memory changes through infancy and childhood. Through this overview, we can see how our memory and memory skills became more and more sophisticated and efficient.

Beginning with infancy, one of the first challenges in understanding infant memory is dealing with the fact that different methods are needed to test such young people, due to their lack of language. Following this, we explore various aspects of memory that have been covered in earlier chapters of this book to see how developed they are in infants and how they mature. After this, we cover the issue of infantile amnesia. After the coverage of issues of infancy and memory, we move on to memory development in children. Again, we look at a number of different memory abilities. Finally, we also look at the phenomenon of childhood amnesia.

INFANCY

The development of memory begins as soon as the nervous system is capable of retaining information. However, not all types of memory are available at the same time or for the same reasons. Here we consider the very early memories of infants. We first consider the challenges of testing preverbal humans to give you an idea of the barriers facing memory researchers. After this we look at some changes in memory that are known to occur during infancy (0–2 years of age). Finally, there is a presentation of the topic of infantile amnesia, or the inability to remember any events from when you were an infant.

Testing the Very Young

Testing infant memory is difficult. The biggest challenge is that infants neither understand nor produce language, which is the medium of most studies of memory. Thus, researchers who study infant memory are immediately faced with the problem of how to assess such nonverbal primates in a way that provides meaningful information. A number of techniques have been created to do this (Hayne, 2004; Rovee-Collier & Cuevas, 2009). Each of these methods uses some motor activity that is already available to the infant—that is, something that the infant does already. What the memory researcher does is assess how this behavior changes as a function of whether something is remembered or not. In this section we look at four examples of methods that have been used to assess memory in infants.

PHOTO 16.1 *Infants learn a great deal in a short period of time—the challenge for memory researchers is to figure out what infants do and do not know given that they lack the language skills of children and adults*

Source: Ryan McVay/DigitalVision/Thinkstock

One way to study infant memory is to use gaze duration/direction or the **looking method** (Friedman, 1972). Infants spend a lot of time looking around the world in a constant effort to understand it. To assess infant gaze as a measure of memory, the infant may be placed in the lap of a caregiver, typically the mother, in the lab. To keep caregivers from unintentionally biasing the infant, they may be asked to listen to music over headphones. Moreover, any displays might be out their line of sight. This method is useful because infants spend more time looking at things that interest them, which are more likely to be new things. In essence, things that are looked at less are things that are recognized, and, thus, are in memory. Increased looking times reflect more of an unconscious, implicit memory novelty preference than an explicit recognition of old items (Snyder, Blank, & Marsolek, 2008).

Another way to determine what infants remember is to use the infants' natural sucking behavior. Babies love to suck on things. This is important because it helps the infant to eat, but they also suck on lots of other things that do not have any nutritional value, such as pacifiers. We can take advantage of **nonnutritive sucking** as a tool to study memory. Rate of sucking changes as a function of whether the infant encounters something old (in memory) or new. This is measured using what are basically high-tech pacifiers that record sucking rate. When something is old, infants suck at a slower rate. However, when something new is introduced, they suck faster (Eimas, Siqueland, Jusczyk, & Vigorito, 1971; Siqueland & Delucua, 1969).

A third technique is a **conjugate reinforcement** paradigm (Rovee-Collier & Fagan, 1981). With this technique, infants lay on their backs in a crib. One end of a ribbon is tied around one of the baby's ankles and the other end is attached to a mobile. Whenever the baby kicks, the mobile moves, which is a very cool thing for infants. They can actually directly control something in the world. They soon pick up on the kicking–mobile movement relationship and spend a good deal of time kicking. Memory for this event can be tested by varying any number of things, such as the amount of time that has passed or the context that can serve as a cue. Essentially, if the infant remembers the situation it kicks more often.

Finally, researchers have found that somewhat older infants can recall information using techniques such as **elicited imitation** (Bauer, 1996, 2002). In these studies, an experimenter does some task, such as assembling a simple toy, while the child watches. Then, after a delay, such as a month later, it is observed whether the infant does the task. This is evidence of recall because it requires the child to deliberately bring to mind a mental representation of the steps needed. It has been found that some form of memory recall begins in infants as young as nine months and becomes stable by two years of age.

Stop and Review

To test infants, researchers have derived clever methods. This is needed because infants lack the ability to use language. Such methods include the looking method, the nonnutritive sucking method, the conjugate reinforcement method, and the elicited imitation method.

Memory and Infancy

Human memory is made up of several components that develop at different rates. This development is guided by neurological changes, as well as the acquisition of abilities that greatly increase memory, including the ability to crawl (around nine months) and the acquisition of language (starting around 10 months) (Hayne & Simcock, 2009). Here, we look at different types of memory and how they are progressing during infancy.

Different types of memory development are associated with various **neurological development** rates. For example, the thalamus and some medial temporal structures, which are important for more primitive types of memory, are nearly developed at birth, whereas the frontal lobes, which are important for controlling the flow of processing in memory, are not completely functional until one year of age or older (Chugani, Phelps, & Mazziotta, 1986). The prefrontal cortex and hippocampus continue to develop through infancy and into childhood (Bauer, 2007). In particular, there is a slow development of the dentate gyrus, which receives information from other parts of the brain. Because the hippocampus is important to memory, if neural signals are not effectively getting into it, then declarative memories are not going to be as reliable. Thus, infant memory, to some degree, is influenced by the readiness of the nervous systems.

What about infant **sensory and short-term** memories? If you remember from Chapter 4, research shows that adults have a very large capacity for iconic memory but they are only able to move four to six items into short-term memory to be processed further before the iconic memory decays away. To infants processing in iconic memory, Blaser and Kaldy (2010) used a design that involved displays of multiple items (e.g., colored diamonds). The infants' task was to notice if any of these objects in the display had changed. They found that infants performed this task as well as adults. Infants have an iconic memory that can process four to six items before it decays away. Thus, the iconic memory seems to be well developed early on, even if the knowledge and skills for how to process that information are not fully developed.

While infants have reasonably well-developed sensory registers, their short-term memory is not up to adult levels, although it matures over time. At six months of age, while infants might be surprised if an object is briefly occluded and then reappears, they are not surprised if it is briefly occluded and changes shape, such as going from a red sphere to a red cube (Kibbe & Leslie, 2011). Thus, infants are holding in short-term memory information that there was something there but not exactly what. As infants develop and acquire language, they start using names for objects to help maintain information in short-term memory (Mani & Plunkett, 2010). In addition, young infants (seven months old) can show short-term memory serial position curves for pictures of adult faces, with primacy and recency effects. Moreover, the recency effect can be easily disrupted (Cornell & Bergstrom, 1983), suggesting that infants are quite prone to interference from other information.

It is clear that infants have various forms of **nondeclarative memory**, such as the ability to learn new motor skills. They can associate the sights and sounds of their parents with care and comfort and acquire a large array of unconscious influences on behavior. Almost immediately, they develop skills to help them get along in the world (e.g., learning to eat). Thus, implicit memory is well on its way at an early age. As an illustration of early nondeclarative memory abilities, infants prefer familiar sounds they heard while in the womb, such as the sound of their mother’s voice. Although nondeclarative memory is present at birth, if not before, it must still also go through a period of development (Rovee-Collier, 1997).

Complex forms of **episodic memory** are present even at very young ages. For instance, using the conjugate reinforcement paradigm, even three-month-old infants remember to kick five days later (Butler & Rovee-Collier, 1989). This is episodic memory, because the kicking is context dependent. When the crib liner is the same during the second session as it was during the first, the kicking rate is higher when compared to when it is different. The crib liner is an episodic retrieval cue (see Chapter 7).

The ability to explicitly remember information for long periods of time increases in accuracy and duration as an infant matures (Hartshorn et al., 1998). For example, using the elicited imitation paradigm, Carver and Bauer (2001) have found that nine-month-old infants can remember and reproduce previously viewed actions up to four weeks later. In contrast, 10-month-old infants can reproduce an action up to six months later. The pattern of retention durations is shown in Figure 16.1 (Bauer, 2007). This pattern of remembering is even evidenced in ERP recordings (Bauer, Wiebe, Carver, Waters, & Nelson, 2003).

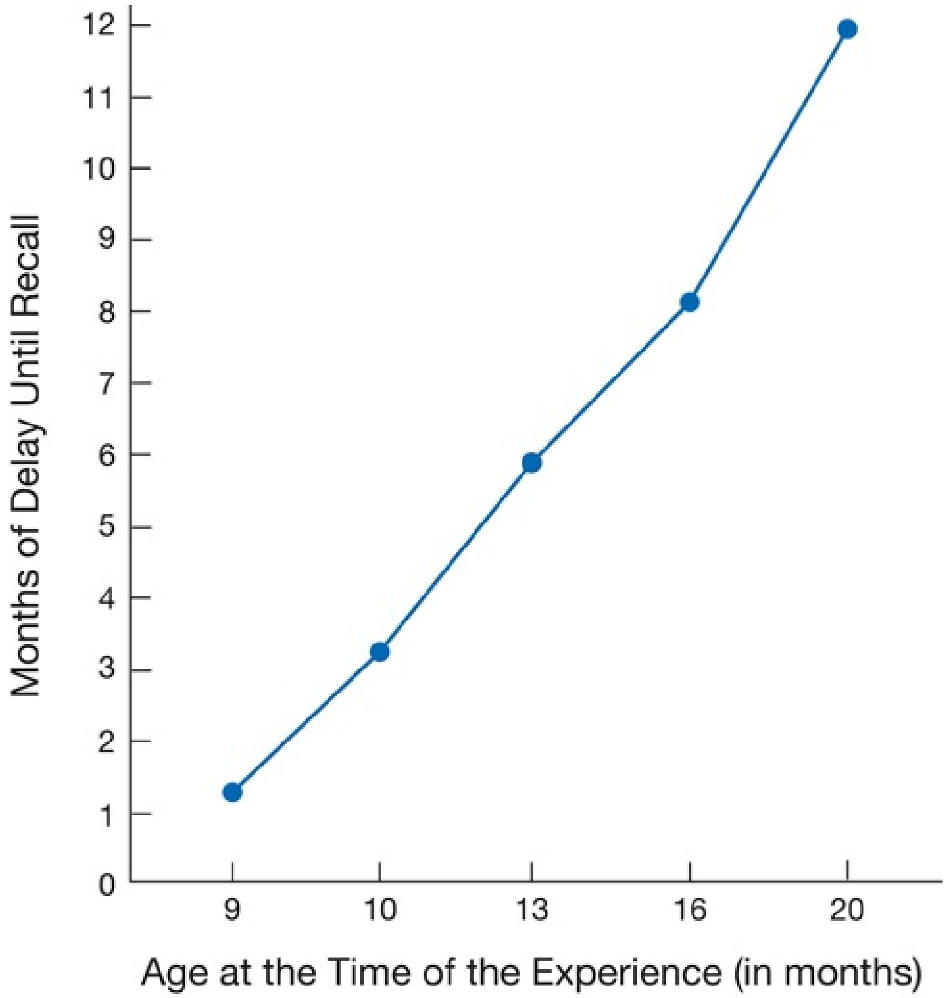

FIGURE 16.1 *Recall Intervals for Children Nine to 20 Months Old From a Number of Studies*

Adapted from: Bauer, P. J. (2007). Recall in infancy. *Current Directions in Psychological Science*, *16*, 142–146

Infant **semantic memory** is advanced enough to allow infants to abstract away from the original information (Mandler, 1988), although early schemas are grounded in perceptual experience (Mandler, 1992). Infants also can create and use categories. As early as three or four months, they make basic-level category distinctions, such as dogs and cats (Eimas & Quinn, 1994; Quinn, Eimas, & Rosenkrantz, 1993), and subordinate category distinctions by six or seven months (Quinn & Tanaka, 2007). By at least nine months of age, infants can abstract new categories, such as those based on object shapes or colors, within a few minutes (Dewar & Xu, 2010). However, it is not until about 14 months of age that infants make distinctions based on superordinate categories, such as knowing that “drinking” and “sleeping” belong to the superordinate category *animals* and that "needs keys" and "giving a ride" belong to the superordinate category *vehicles* (Mandler & McDonough, 1996). Knowledge of finer level categories remains elusive until over two years old (Mandler, Bauer, & McDonough, 1991).

Semantic memory also involves the identification of drawings and pictures. To do this, one must match a more abstract picture with a memory of a real object, which is not as simple as it sounds. To test this ability, Hochberg and Brooks (1962) raised their own child from birth to age 19 months in an environment in which objects in pictures were never named and where pictures were relatively unavailable, to the point of not letting their child see picture books and removing labels from baby food jars. Despite this, at 19 months, their child was able to identify pictures and drawings with no problem. Thus, the ability to abstract information occurs without any explicit practice or training.

Stop and Review

Memory development in infants reflects differential patterns of maturation. While some neural structures are well developed early on, others are not. Some of the more developed memory systems in infants include the sensory registers and nondeclarative and semantic memory abilities. However, other types of memory are undeveloped, including short-term memory and episodic memories (in terms of memory for specific events), although the rudimentary elements of these systems are in place.

Infantile Amnesia

What is the first thing that you remember? The very first thing. It is time to think about our memories from when we were infants. But wait. Where *are* they? This absence of early memories is called **infantile amnesia**. Most adults, if they think about it, find that their earliest memory is not from infancy but from when they were between the ages of two and four (Mullen, 1994; Usher & Neisser, 1993).[1] These initial memories tend to have information about where the event took place and what happened, but few other details, such as who else was there, their thoughts at the time, the weather, their age, how long the event lasted, and what was worn, unless these are easily inferred or central to the memory (Wells, Morrison, & Conway, 2014). These very first memories tend to be earlier in age for women and for those people with higher levels of education (Kingo, Berntsen, & Krøjgaard, 2013). These earliest memories are often fragmented, such as a memory of standing in a room, whereas more episodic memories of whole events are regularly reported about a year later (Bruce et al., 2005). The phenomenon of infantile amnesia is surprising given that infancy is a time when people are actually learning a very large number of things at a rate faster than any other time in their lives.

As an example of infantile amnesia, my earliest memory is from when I was two and a half years old. My parents had just moved from Ohio to Wisconsin and we were living in a trailer park until they could find a house. It was late December and I remember ice creeping in underneath the door. Because my family was new in town, some of my father's new coworkers wanted to help out. So, one of them came to the trailer one evening dressed as Santa Claus to give me a thrill. (He already had a Santa suit because he had discovered that, when he wore it to a bar, someone always wanted to buy Santa a drink.) When he walked into the trailer, I was terrified. I remember crying and screaming and running into my bedroom to get away from this big, red, creepy-looking guy who had burst into my home and started ho-ho-hoing at me.

Occasionally, people report memories from earlier ages. However, we need to have a bit of skepticism before we accept these as real. The problem is that many of these "memories" were generated in response to seeing pictures, hearing stories told by older relatives, or other sources. Thus, they are not memories of the event itself but are generated from mental images and event models created at the time people heard those descriptions. Thus, while people are remembering some event from when they were very young, these may have been generated in the same way that false memories are (see Chapter 13).

So, what happens to memories of a person's life before the age of two or so? Why do we have no conscious memories of this period of our lives? Nearly all of the events are forgotten. Several explanations are now presented for infantile amnesia. One of the first people to take note of infantile amnesia was Sigmund Freud (1899/1938). His explanation was rooted in his **psychodynamic view**. In Freud's scheme, many of people's psychological problems involved sexual thoughts and desires. Infants are no exception. For Freud, when we are infants we go through a period of sexual thinking and wishing. Part of that involves a desire to be sexually intimate with our opposite-sexed parent. As we mature, we take on the rules and norms of our culture as part of the development of the superego. At this time, we learn that our incestual thoughts are taboo. To protect ourselves from this threatening and horrible knowledge about ourselves, our unconscious blocks from consciousness all memories from this time. This grand-scale repression is so successful that people have no memory of when they were infants.

Freud's theory makes interesting reading and it fits well into his broader theories. However, there are few people today who accept his view on infantile amnesia. Most contemporary explanations focus on other factors.

TRY IT OUT

This project is about assessing memories for the past from adults and plotting out infantile amnesia. First, put together a list of 30 nouns. These words will be used as cues for people to remember events from their past.

You need at least 12 participants, but more is better. For each participant, read the words aloud. Their task is to recall the first event from their childhood that the word brings to mind. They should write down a one- or two-sentence description of each memory. Be sure to tell them that they do not need to write down memories that they would not want other people to read about because they are too embarrassing or upsetting. Give people about a minute to write down a brief description of each event. After you have gone through your list of words, have your participants go through their events and write down how old they were at the time (alternatively, have them write down the date as close as they can get to it). This is the data of most interest. You will also need your participants' current ages. If you get their birthdates, then you can be more precise.

After your participants have gone through and dated all of the events that they wrote down, collect their response sheets. Then, tabulate the age that the person reported being in terms of how many years old they were. This should give you a percentage of responses for each age (zero, one, two, three, etc.). Then plot their data as a function of age. What you should observe is that there are fewer and fewer memories as you plot younger and younger ages. Moreover, there should be hardly any memories for the age of two or younger. This is because of infantile amnesia.

Modern Views

There are several modern ideas regarding what causes infantile amnesia, and there are likely multiple factors that contribute to it. There are a number of changes that move people from a state of not remembering much about their lives to the awareness that is autobiographical memory. The **multicomponent development theory** (Fivush & Nelson, 2004; Nelson & Fivush, 2004) embraces the idea that there are number of memory abilities or components that bring about this new type of memory. Note that, for these modern views, unlike Freud’s account, infantile amnesia is not really an amnesia—a catastrophic forgetting—but an inability to form long-lasting conscious, personal memories.

A **neurological account** of infantile amnesia is based on changes in neural structures in the course of development. Humans are born neurologically immature. The brain quadruples in size over the course of development to adulthood. Most of this change is not in an increased number of neurons but an increase in the number of connections. The hippocampus, an important structure in creating new memories (see Chapter 2) is relatively undeveloped at birth. It does not reach adult form until a child is a few years old (Nadel & Zola-Morgan, 1984). The dentate gyrus is particularly slow in developing and there is a high rate of neurogenesis in this area, which may disrupt memories that are being stored there (Josselyn & Frankland, 2012; Lavenex & Lavenex, 2013). The critical role of the hippocampus in binding together various types of information to create episodic and autobiographical memories lends support to the idea that it is involved in infantile amnesia. If an infant cannot create effective episodic and autobiographical memories because the neurological processes are just not fully there yet, then this would support the absence of memories from this time in our lives.

This role of the development of the hippocampus in infantile amnesia has also been tied to embodied cognitive processing (Glenberg & Hayes, 2016). This thinking is rooted in the idea that the hippocampus is important for spatial processing, as evidenced by the presence of place cells, grid cells, and such. For this view, the offset of infantile amnesia is a function of greater spatial navigation on the part of people around the age when infantile amnesia begins to lift, which is commensurate with the increased use of navigation aspects of the hippocampus increasing at this time. The increased use of contextually based cells then improves long-term term retention of episodic and autobiographical knowledge.

In addition to hippocampal development, infants have less-developed frontal lobes. This part of the brain is important for binding contextual factors in memory, allowing for such things as source monitoring (see Chapter 13). This inability to link different aspects of experience leads to an inability to form autobiographical memories (Newcombe et al., 2000). Finally, during infancy and early childhood, the ability to consolidate memories is underdeveloped, leaving people more prone to interference from later events (Bauer, Burch, Scholin, & Güler, 2007), thereby contributing to infantile amnesia. In general, the problem of infantile amnesia reflects a period of time when infants are acquiring, but not retaining, complex and neurologically sophisticated episodic memories (see

Chapter 12).

Another theory of infantile amnesia, the **schema organization view**, is that infants are trying to understand how the world works and are still developing their schemas (Chapter 9). Infantile amnesia is related to a development in the understanding of how adults think and talk about the world and the passage of time. For example, a child might remember what typically happens during a trip to McDonald's but not remember any of the details from a given trip. Young children with underdeveloped schemas may focus on inappropriate aspects of an event. As their schemas become more developed, they have difficulty retrieving the prior memories that were formed with the old schemas. That said, there seems that young children can form episodic memories. The difficulty is that they are forgotten much faster (Nelson & Gruendel, 1981).

An important thing to note about the time when infantile amnesia lifts is that this is also the time when **language development** is making significant strides (Nelson, 1993). Infantile amnesia may reflect an inability to organize information into a coherent life narrative, which can then be used to help retrieval. Early on, infant memory has two roles: either as a generic schema-driven memory or as a repository for temporary episodic memories. With the advent of language and the need to share experiences with others in our social context, autobiographical memory is developed. So, the chaotic jumble of memories that is infantile amnesia is displaced with the organization of the new autobiographical memory. This is supported by work showing that preverbal children do not translate nonverbal knowledge into verbal information after they learn how to talk about those events. The memories appear to stay nonverbal (Simcock & Hayne, 2002), which makes them harder to retrieve (Richardson & Hayne, 2007).

Finally, for the **emergent self view**, there are significant changes during infancy in how a person understands himself or herself (Howe, 2003; Howe & Courage, 1993). Infantile amnesia is a function of people developing a sense of self as a unique and identifiable entity. Newborn infants lack a clear sense of self as a separate entity from the environment. The development of the self is divided into the acquisition of the "I" and the "me." The "I" is the subjective sense of self as a causal agent, whereas the "me" is the objective sense of self, such as your personal features. This latter sense emerges around 18 months and is fairly well established by 24 months. Once this concept of self is established, autobiographical memory can be constructed around it. Again, the offset of infantile amnesia corresponds to the onset of autobiographical memory.

As noted at the beginning of this section, the multicomponent development theory (Nelson & Fivush, 2004) is the idea that there are number of memory abilities or components that emerge to bring about autobiographical memory. These components include not only the development of an adequate episodic memory system but also the development of language and narrative skills and an understanding of how adults think and talk about the world and the passage of time, as well as how people understands themselves. Thus, there are multiple causes that bring about the emergence from infantile amnesia.

A number of these factors, such as the use of schemas, the development of language, and the emergent idea of self, come together and are influenced by the culture one is embedded within (Wang, 2003). Culture can influence the age at which people report their first memories. As an example, children whose mothers reminisce about the past, such as where the child went and what they saw, emerge out of infantile amnesia faster than children whose parents spend less time talking about events in the past (Fivush & Nelson, 2004). These children also grow to be better at explaining things because they have a head start on understanding narrative structure and style. As another example, people in Western cultures, such as the United States, come out of infantile amnesia six months earlier than people living in Asian cultures (Wang, 2003). This may be because in these cultures children interact differently with adults, with a greater focus on the self in Western cultures.

Stop and Review

The inability of adults to remember most memories from when they were infants is infantile amnesia. This is contrast to the furious pace that infants are acquiring new knowledge. Freud thought that this was a period of catastrophic forgetting, a genuine amnesia, in which people actively represses memories. More modern theories suggest that this is not a genuine amnesia but an immature ability to form conscious, personal event memories. This is due to an immaturity of the nervous system, a lack of requisite semantic knowledge, such as schemas, a lack of language skills to organize and structure experiences, and an absence of a clear self-concept around which memories can be structured. These multiple causes converge, along elements of culture, to help infants move from not being able to remember events for long to being able to reliably retain memories.

CHILDHOOD

As people leave infancy and move into childhood, memory continues to develop. For our purposes, childhood is the period of time from ages three to 17, although much of what we have to say here applies to children under the age of 12. During this time the nervous system continues to develop until people reach early adulthood. These changes, of course, influence memory. For example, the speed with which children execute memory processing increases exponentially until the mid-to late teens (Kail, 1991). The nervous system is becoming more efficient.

Neurological and Short-Term/Working Memory Processes

As people progress through childhood, **neurological development** continues. For example, the dentate gyrus of the hippocampus continues its move toward adult levels until the age of five. Moreover, there is a pruning of neural connections, with adults having fewer connections than children, although there is an overall increase in brain size (Bauer, 2009). Thus, the brain is becoming more fine-tuned and efficient at processing information and retaining it for later.

Although the sensory registers are well developed (Engle, Fidler, & Reynolds, 1981), the ability to use **short-term/working memory** consistently improves. For instance, there is an increase in the rate and effectiveness of rehearsing information to keep it in memory. This results in an increase in the amount of information being rehearsed (Flavell, Beach, & Chinsky, 1966; Ornstein, Naus, & Liberty, 1975). In other words, memory span is getting larger. Short-term memory span improves from about two items for two-year-olds to about six items by the time a child is nine years old (Dempster, 1981). With the larger memory span, overall performance increases. Another factor that is improving is the speed with which children articulate information. As a reminder, the word length effect is the finding that people remember fewer words as the words' articulation times increase. This is because longer words are more likely to decay in the phonological loop (see Chapter 5). As children age, they can pronounce words faster. This results in older children having larger memory span scores (Hulme, Thomson, Muir, & Lawrence, 1984). This relation between rehearsal speed and span is shown in Figure 16.2.

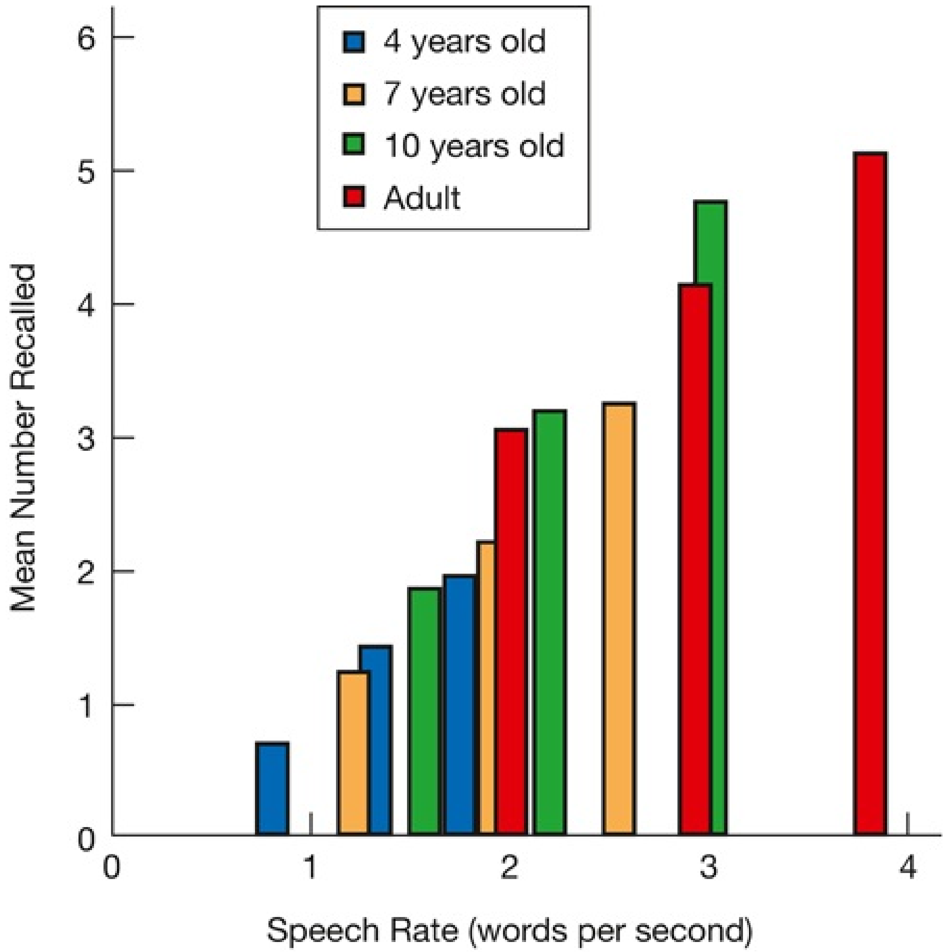

FIGURE 16.2 *A Boy's Semantic Memory Network for Dinosaur Concepts*

Adapted from: Chi, M. T. H., & Koeske, R. D. (1983). Network representation of a child's dinosaur knowledge. *Developmental Psychology*, *19*, 29–39

This increased articulation speed reflects a general increase in processing speed that occurs as children grow older (Kail, 1991). This increased speed influences both verbal and visual-spatial working memory (Kail, 1997), not just the maintenance of a list of words.

Episodic Remembering and Forgetting

In childhood there is also an increase in the degree of information structure and organization, and this is reflected in **episodic memory** retrieval success (Bjorklund & Zeman, 1982). That is, how well children can learn new episodic information is reflected in their ability to structure and organize the materials presented to them. The better they can organize it, the more they remember, and their organization skills are improving with age. For example, for memory for names of furniture found at home, younger children (around age 10) tend to organize memory based on furniture category (e.g., chairs, tables, etc.), whereas by age 16 children had switched over to organizing around spatial categories (e.g., living room, dining room, etc.) (Plumert, 1994). This second organization is more efficient and effective. Thus, children change their thinking and memory to more sophisticated ways of structuring and organizing knowledge and experiences, which then results in improved long-term retention. As another example of changes in the effectiveness of organizing and structure information, children show superior memory for information encoded in a survival context (Otgaar & Smeets, 2010).

STUDY IN DEPTH

As noted in this chapter, children generally score lower than adults on memory span tests. However, this can be influenced by a child's interests. This was shown in a study by Lindberg (1980). This study directly compared two groups of 40 participants each. One group was made up of college students at Marshall University (around the age of 20). The other was made up of third-graders (around the age of 9).

Prior to testing, two lists of items were created. Each list had 30 items. One list was words from a standard list of categorized word norms that are typically used in working memory span studies. The other list was composed of items with which the children had more familiarity. These included the names of cartoon characters, children's books and films, and television show characters, as well as the names of teachers and rooms at their elementary school. Thus, college students were more likely to be familiar with the words on the first list, whereas the third-graders were more likely to be familiar with the items on the second list.

During testing the word lists were read at a relatively slow rate of one word every three seconds. At the end of each list, people were asked to recall as many of the words as they could. They were told to guess if they were unsure and not to worry about spelling. After all, many third graders are not as good at spelling as college students. After they were done, the recall sheets were collected by an experimenter.

What was found was that when children were given words pertaining to topics for which they had greater knowledge, such as the names of cartoon characters, memory spans improved to that of a college student, but college students’ memories were better for categorized lists of words, as shown in Figure 16.3. The ability to remember materials is at least partially a function of people’s knowledge base. If items are drawn from children’s knowledge bases, the children’s performances are much better. This calls into question concerns about just how effective the working memory abilities of children may be, with children having better memories than they are sometimes given credit for.

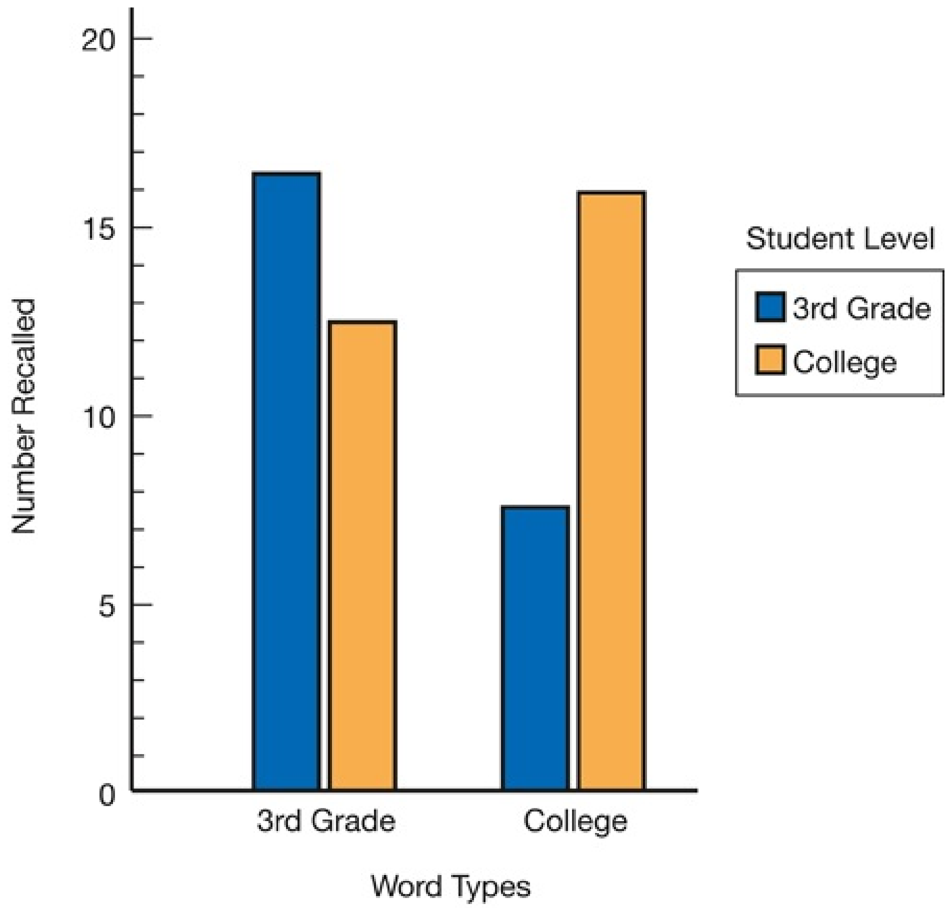

FIGURE 16.3 *Relation between Person’s Speech Rate and Working Memory Span Scores Broken Down by Different Age Groups*

Adapted from: Hulme, C., Thomson, N., Muir, C., & Lawrence, A. (1984). Speech rate and the development of short-term memory span. *Journal of Experimental Child Psychology*, *38*, 241–253

Not only does increased age during childhood improve episodic memories for the past, but it also improves memory for the future. For example, there are age-related improvements in **prospective memory**. Children between the ages of four and six are less effective at prospective memory tasks, often forgetting that they are supposed to do something in the future. However, by the ages of 13 or 14, prospective memory abilities are at adult levels. That said, they then start to decline through a person's 20s to 40s (Maylor & Logie, 2010; Zimmermann & Meier, 2006). This is in contrast to retrospective memory, which continues to improve throughout early adulthood.

Also developing with childhood is the ability to engage in mental time travel for **episodic future thinking**, which appears to emerge between three and four years of age and shows a particularly large improvement from ages four and five (Atance 2008; Atance & O'Neill, 2005), in a way that parallels young children's ability to retrieve memories for past events (Busby & Suddendorf, 2005). It should be noted that it is easier for children to imagine future events for other people than themselves, suggesting that there are some delays in processing information about the self (Russell, Alexis, & Clayton, 2010). While this does increase with age, as do other future-oriented abilities such as delayed gratification and prospective memory, these developments in future-oriented thought do not seem to be strongly correlated with one another, suggesting that there are different underlying processes for each of them (Atance & Jackson, 2009).

The improvements observed during childhood are focused not only on the ability to store information but also on the ability to retrieve knowledge later. This includes the management of the **interference** from competing memory traces. Early on, during the preschool years, children are more prone to interference, particularly retroactive interference, which can result in high levels of forgetting (Darby & Sloutsky, 2015a). That said, if there are long delays between related sets of information, such as 48 hours, then the retroactive interference effects can be greatly attenuated as children have an opportunity to consolidate their knowledge (Darby & Sloutsky, 2015b). For older ages, such as around the age of 12, children show similar interference effects as adults (such as a fan effect) and they can better organize information to reduce that interference (Gómez-Ariza & Bajo, 2003). Moreover, inhibition appears to help children to the same degree as adults. Children show retrieval practice and part-set cuing effects that are similar to adults (Zellner & Bäuml, 2005), as well as similar retrieval practice effects (Aslan & Bäuml, 2010). Finally, for directed forgetting, Harnishfeger and Pope (1996) tested six-, eight-, and 10-year-olds, along with college students, and found that the ability to inhibit information increased with age, with 10-year-olds doing as well as the adults.

Semantic Memory

As children acquire have more experience with the world, their **semantic memory** becomes more complex. This does not mean that there is no complex semantic information at all in younger children. There can be if the child has taken the time and effort to learn it. Even at a particularly young age, a child can have a complex semantic network of a particular domain. For example, a portion of a four-and-a-half-year-old boy's semantic knowledge of dinosaurs is shown in Figure 16.4 (Chi & Koeske, 1983). This boy's semantic memory for dinosaur knowledge is fairly complex and well organized. Many of the armored dinosaurs are in a cluster and so are the large plant-eaters. When the boy recalled the names of dinosaurs, the ones he recalled most often were those with the greatest number of semantic links.

For semantic memory, children also develop more and more complex schemas and scripts for commonly experienced aspects of the world. This is evident even around the age of three (Nelson & Gruendel, 1988). These schemas and scripts become more numerous and continue to developed as a child ages. As children mature, their scripts include more details and minor steps in whatever the process might be. The desire to develop and improve scripts and schemas in young children can be clearly seen in their desire to cling to set routines where they can predict and understand what is happening.

For categorization, even young children show some proficiency at this process. However, there are changes that do occur over the course of development. For example, preschool children are likely to assume that members of the same basic-level category have a similar internal structure (same kind of stuff inside) but do not do this for superordinate-level categories until second grade (Gelman & O'Reilly, 1988). Another thing that changes is how natural kind and artifact categories develop (Gelman, 1988). As a reminder, natural kind categories are for things in nature, such as animals and plants. Members of a natural kind category are often superficially similar. In comparison, artifact categories are made of items created by people for various uses and are defined by how an object is used, not its appearance. For example, a screwdriver is more similar in appearance to a butter knife, but the knife is more likely to be classified with a fork. Categories are driven largely by appearance for young, preschool children, which is a natural kind bias, but not by older children, who develop an alternative way to create categories that involves the memory processes needed for artifact categories.

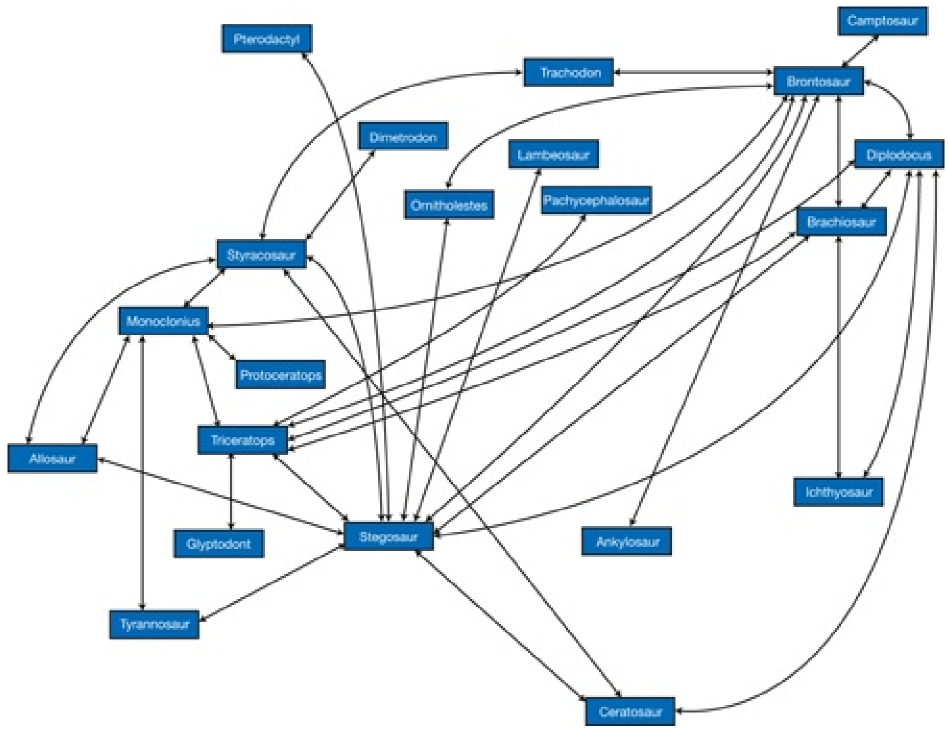

FIGURE 16.4 *Influence of Domain of Interest Words on Memory Span in Children and Adults*

Adapted from: Lindberg, M. A. (1980). Is knowledge base development a necessary and sufficient condition for memory development? *Journal of Experimental Child Psychology, 30,* 401–410

Specialized Memory

The improvement in memory skills, as well as the emergence from childhood amnesia (see next section), is tied to the onset of a more coherent and elaborate life narrative as **autobiographical memory** skills continue to develop, particularly in adolescence (Habermas & Bluck, 2000; McLean, 2005). This autobiographical narrative memory structures memories of experienced events. It provides a sense of the meaning and flow of the events in people's lives as they move through adolescence. This is done, in part, in terms of giving memory traces more temporal and causal coherence (such as developing a well-ordered autobiographical narrative), as well as thematic organization. It also provides more links to join various elements of experience together, making it more likely that they will be remembered later.

Given that there are developmental changes for a variety of memory systems as children grow older, how does this affect **memory and reality** judgments in children? An important aspect of this is source monitoring. In general, children are not as effective as adults at source monitoring, particularly for internal and external source monitoring, compared to reality monitoring (Lindsay, Johnson, & Kwon, 1991; Parker, 1995; Roberts & Blades, 2000). However, these skills do improve. Thus, young children are more likely to have difficulty accurately remembering where a given piece of knowledge was acquired.

False memories generated using the DRM paradigm (see Chapter 13) changes as children grow older. As seen in Figure 16.5, it starts out relatively small or absent in five-year-olds. Eight-year-old children show a small effect and 11-year-old children show an effect that is larger but still smaller than adults (Brainerd, 2013). This is related to the fact that children's semantic memories, which are behind the generation of this false memory effect, are still developing. The more developed people's semantic memories are, the easier it is to draw inferences and the more likely that gaps will be filled in and be confused as being real memories. The source of that knowledge is then lost, leading to belief in the false memory.

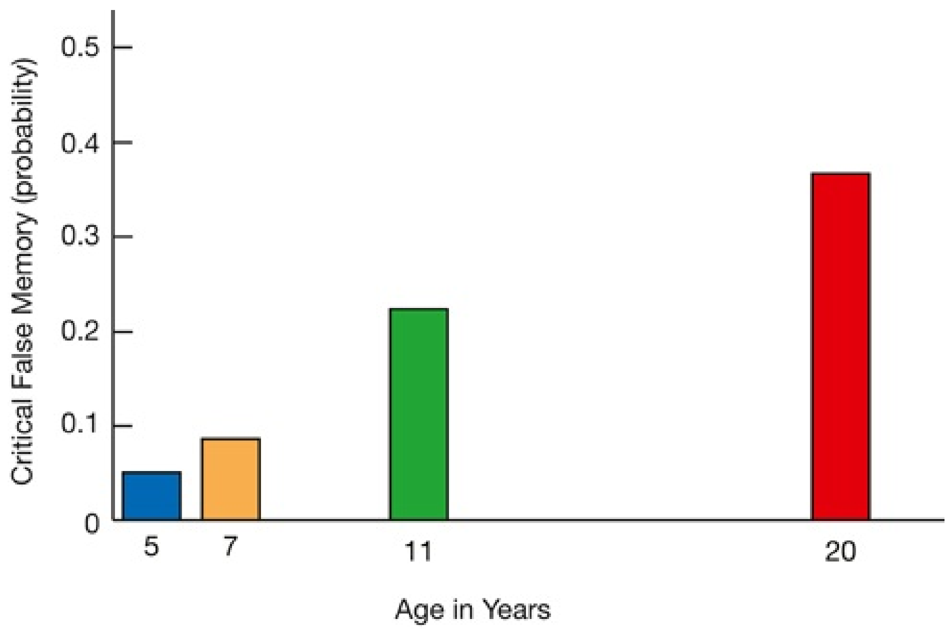

FIGURE 16.5 *Probability of Making a False Memory Error on a DRM False Memory Task*

Adapted from: Brainerd, C. J. (2013). Developmental reversals in false memory: A new look at the reliability of children's evidence. *Current Directions in Psychological Science*, *22*(5), 335–341

The ability of children to distinguish what really happened from what did not plays into important **memory and the law** situations where children may be eyewitnesses who need to give testimony. As is detailed in Chapter 14, eyewitness memory is easily distorted when a witness has been exposed to misleading postevent information. Given this, how reliable are children's eyewitness accounts in the face of underdeveloped memory systems? The research here is a bit mixed and complicated. In light of that, some simple points can be made (Ceci & Bruck, 1993). First, children are able to provide accurate eyewitness testimony. In the absence of external influences, a child's memory is similar to an adult's, provided that a child understands the event.[2]

Given that, it is also the case that children are more susceptible than adults to misinformation (Poole & Lindsay, 2001, but see Otgaar, Howe, Brackmann, & Smeets, 2016), even when they encounter a single instance of misinformation from an adult (Bruck & Ceci, 2004). This may occur because adults are likely to serve as authority figures for children, making them less able to resist the misinformation. Note that the authority figures are actually implanting false memories in the children. The children's reports do not simply reflect greater compliance with what children may perceive as the demands or wishes of the adult asking the questions (Otgaar, Verschuere, Meijer, & Oorsouw, 2012). This can be mitigated to some degree by repeated interviews but only when their prior memories are fairly strong (Goodman & Quas, 2008).

In addition to issues concerning misleading postevent information, children may also have some problems with lineup identification. In a meta-analysis of 91 studies, Fitzgerald and Price (2015) reported that children do more poorly in lineup tasks. They are more likely to make false positives and are less likely to correctly identify a culprit. This may reflect general development trends in the processing and storage of detail information in memory. Younger children (those not yet seven years old), have particular difficulty storing detailed information about experienced events, whereas older children develop an ability to store and retrieve such details (Strange & Hayne, 2013). This is obviously of importance to investigators trying to solve a crime.

Another important aspect of memory that is improving during the course of childhood development is **metamemory** (Bjorklund, Dukes, & Brown, 2009). For example, in a short-term memory serial position curve (see Chapter 4), to get the most out of the recency effect, people should recall the last items first before they are displaced out of short-term memory. People develop an implicit understanding of this and adults often do recall items this way. However, young children lack this awareness and are less likely to start with the final items. This has a net effect of reducing the overall amount of knowledge retrieved. Samuel (1978) found that this strategy was used infrequently by first-graders but it was used progressively more often as children moved into the college years. Metamemory strategies also develop in terms of a general increased awareness of the need to rehearse information to maintain it. This sort of simple memory strategy begins to emerge in two-year-old children (DeLoache, Cassidy, & Brown, 1985). For example, a toy might be hidden under an object and children will continue to glance or point in that direction, suggesting an active attempt to maintain this information in memory.

PHOTO 16.2 *Memory and learning skills continue to improve as children grow older; one of the greatest sources of this improvement in children's knowledge of how to control and use their memories*

Source: dolgachov/iStock/Thinkstock

Staying on the topic of metamemory and development, there is evidence that proneness to the hindsight bias decreases across childhood (Bernstein, Erdfelder, Meltzoff, Peria, & Loftus, 2011). This decrease is shown in Figure 16.6. Preschoolers are less likely to realize that something they learned is not something that they knew all along. In comparison, older children develop an awareness that there is a change in the knowledge from not knowing something to knowing something. Young children's lack of awareness that they are storing new knowledge in memory may contribute to the lack of effort that they exert in trying learn new things.

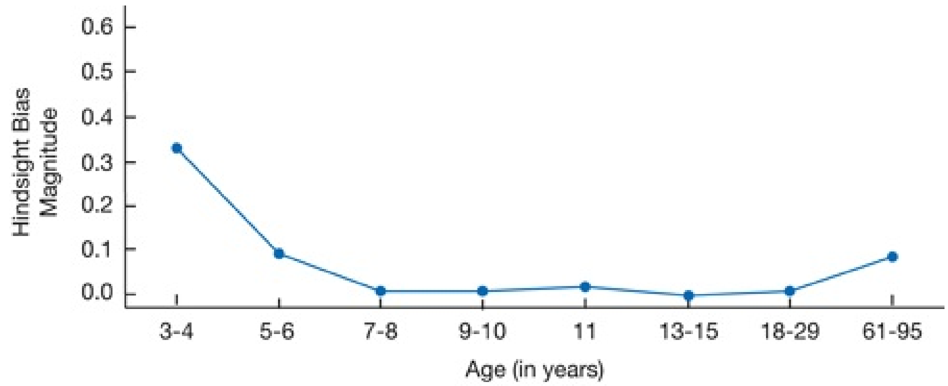

FIGURE 16.6 *Magnitude of the Hindsight Bias From Childhood to Old Age*

Adapted from: Bernstein, D. M., Erdfelder, E., Meltzoff, A. N., Peria, W., & Loftus, G. R. (2011). Hindsight bias from 3 to 95 years of age. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 37*(2), 378–391

Improving Your Memory

At this point there is not much you can do about your childhood memory. That period of your life has come and gone. However, there is some insight that can be gained from understanding why children forget things to develop ways to improve your own memory. As noted in the chapter, one of the biggest improvements is for children to gain an awareness of how their own memories work. As Chapter 15 detailed, people's metamemory awareness is far from perfect. You, like most people, probably do not have the best insight into how your own memory works. As such, you can improve how well you remember things by becoming more aware of when you may be overestimating the likelihood of remembering something in the future. If you encourage yourself to use the principles that you have been learning in this book, you will find that you will better learn and remember more things. You started along the trajectory of greater memory awareness and control as you matured as a child. Now, allow yourself to continue this process.

The ability to organize and structure information also continues to mature (Paris & Lindaur, 1976). As a reminder, the more that information is structured, the better it will be remembered later. An example of this is inferring that a spoon was used when reading the sentence "the truck driver stirred the coffee in his cup." If this inference is made, then the word "spoon" is an effective memory cue for this sentence. Older children are more likely to make implicit associations to help organize the information and improve memory. This also assists in the emergence and development of autobiographical memory.

Stop and Review

Memory continues to develop in childhood. Short-term/working memory becomes more efficient, along with faster processing speed and better inhibition of irrelevant information. Episodic memories are more structured, allowing children to better process event knowledge, and they are less susceptible to interference. For semantic memory, children develop more elaborate and detailed categories, schemas, and scripts. These allow them to better organize and structure, and so remember, more experiences. For autobiographical memory, life narratives become more complex and better structured. In terms of memory and reality, while children are better at monitoring source information, they become more susceptible to DRM false memories. Relatedly, although children can be effective eyewitnesses, they may be more prone to distortion from misleading information. Finally, as they grow, children become more aware of the limits and abilities of their own memories.

CHILDHOOD AMNESIA

As noted earlier, there is a period of time when adults are unable to remember any events from when they are infants. This is infantile amnesia. After people emerge out of infantile amnesia, it is not the case that there is normal adult memory at that time. Instead, memory for experienced events is better but it is still quite spotty. Thus, this is a period of time known as **childhood amnesia** (Jack & Hayne, 2010). While infantile amnesia lasts up to around the age of three or so, childhood amnesia lasts up to around the age of seven or so. If you reflect back on your own childhood, you are likely to find that your memories for events prior to the age of eight are quite spotty relative to your memories for other ages. This is worse than what would be expected based on normal forgetting curves.

Forgetting and Consolidation

So, why does childhood amnesia occur? One explanation is that there is a **constant rate of forgetting** and a **lack of systems consolidation** abilities. As a reminder, in adults, the rate of forgetting is captured by a power function. Moreover, the rate of forgetting slowing down at longer retention intervals. For a power function, the size of the exponent provides an index of the rate of forgetting. Figure 16.7 illustrates how this exponent continues to decrease as people move from middle childhood to middle age. Part of what is contributing to this slower rate of forgetting is that some memories have been consolidated in the cortex and so are taken out of the pool of memories that can be subsequently forgotten. However, for children, the rate of forgetting is not best fit by a power function but by an exponential function. This suggests that, for children, far fewer memories are being consolidated in the cortex. Thus, while children have more developed neurological structures, have reached a level of schema development and language processing to help them structure knowledge, and have acquired the ability to form episodic memories and embed them into an autobiographical narrative, they still are not at adult levels in the ability to consolidate those conscious event memories in a way that makes them available and accessible over long periods of time.

Life Narrative

As children reach the ages of seven and beyond, the ability to consolidate information is improved. As a result, the rate at which information is forgotten improves as well (Bauer & Larkina, 2014). Part of this improvement in memory may also be related to the ability to form more complete narrative accounts of experienced events. This makes the memories less episodic and more autobiographical (Bauer, 2015; Willoughby, Desrocher, Levine, & Rovet, 2012). By adolescence, the cultural life scripts children have for how a person's life should unfold are very similar to those of adults (Tekcan, Kaya-Kizilöz, & Odaman, 2012). If younger children are encouraged to form narrative accounts of experienced events, then their memories for those events improves (Wang, Bui, & Song, 2015). Thus, the emergence from childhood amnesia is due to better memory consolidation and better autobiographical memory structures.

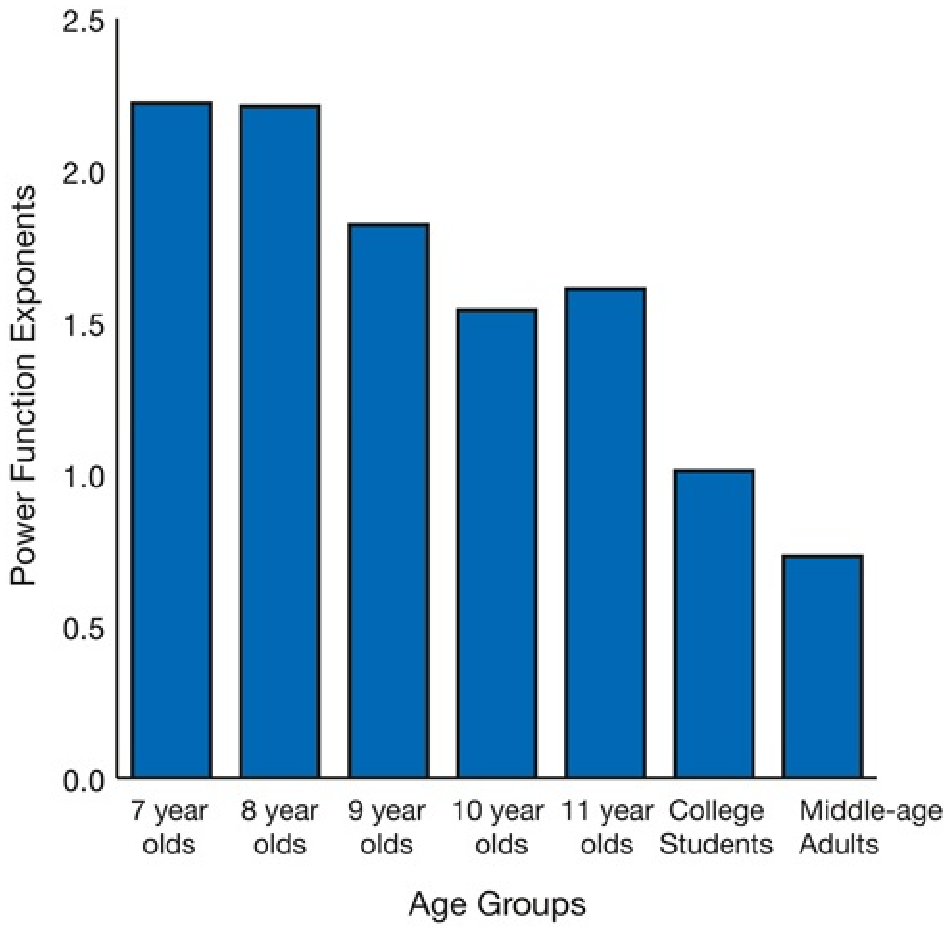

FIGURE 16.7 *Changes in the Rate of Forgetting Over the Course of Development, With the Rate of Forgetting Captured by the Exponent Value of the Best Fitting Power Function*

Adapted from: Bauer, P. J., & Larkina, M. (2014). Childhood amnesia in the making: Different distributions of autobiographical memories in children and adults. *Journal of Experimental Psychology: General*, *143*(2), 597–611

Stop and Review

While children have moved beyond infantile amnesia, their memories are still not up to adult levels. Up until the age of eight, episodic memories are spotty and fragmented. They are forgotten at a rate faster than one would expect. One reason for this is that children have not fully developed the ability to consolidate episodic memories. Also, around age eight there is an increase in the formation of the life narrative of autobiographical memory, which helps provide structure to experiences, leading them to be better remembered.

PUTTING IT ALL TOGETHER

Infants and children go through a time of dramatic change in the ability to remember. When dealing with infants, the first challenge is to find a way to test their memories. Several methods have been developed, including the looking method, nonnutritive sucking, conjugate reinforcement, and elicited imitation. Neurologically, infancy and childhood are times of neurological development, with some neurological structures being well developed at birth, whereas others are still in a relatively primitive state. The hippocampus is an important memory structure that continues to develop all throughout childhood. The presence of some neurologically developed structures at birth is why some types of memory are ready to go, even if the content to fill them is not there yet. These include the sensory registers, nondeclarative memory, as well as some episodic and semantic memory abilities.

Other types of memories go through a great deal of change and development during childhood. Working memory capacity increases in the speed of processing as well as an increase in the cognitive control and metamemory skills needed to manipulate information. For episodic memory, there is development in the ability to effectively bind and maintain information. Finally, semantic memory acquires the content of world knowledge, which becomes more structured and organized all the time, boosting the retention of any memories that draw upon this knowledge.

The lag in memory abilities and content bring about the periods of infantile and childhood amnesia. The emergence from these comes about with the development of neurological structures, such as the hippocampus and a continued improvement in the ability to consolidate declarative event memories in the cortex. Outside of neurological changes, there is the growth of appropriate semantic memories, the expansion of language abilities to structure and tag memories, and the emergence of a clear self-concept to structure autobiographical memory around. More generally, infantile and childhood amnesia are the inverse of the onset and development of autobiographical memory and the life narrative. Autobiographical memory provides a means to organize and give meaning to your life. Overall, many elements come together to move infants and children from a state of inability to remember events to the ability to do so regularly and reliably.

STUDY QUESTIONS

1. What are some of the various ways of testing infants' memories and how do they work?
2. What memory systems are well developed in infancy and which are still immature?
3. What is infantile amnesia? What are some major theoretical accounts for why it occurs and why does it go away?
4. What are some of the major changes in memory that are observed during childhood?
5. What important role does metamemory play in changes in memory during childhood?
6. What is childhood amnesia and how does it relate to infantile amnesia?
7. What role does autobiographical memory play in changes in memory as a child moves through adolescence?

KEY TERMS

- childhood amnesia
- conjugate reinforcement
- constant rate of forgetting
- development
- elicited imitation
- emergent self view
- infantile amnesia
- lack of systems consolidation
- language development
- looking method
- multicomponent development theory
- neurological account
- neurological development
- nonnutritive sucking
- psychodynamic view
- schema organization view

EXPLORE MORE

Here are some additional readings to explore that can provide you deeper insight into some of the ideas of how memory changes across infancy and childhood.

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NOTES

1 It is possible to have event memories from as early as 18 to 24 months, but not earlier (Howe, 2003). Also, note that, because of the phenomena of forward telescoping (see Chapter 12), initial memories may be earlier on average than reported (Wang & Peterson, 2015).

2 For a case study of nine- and seven-year-old children's eyewitness memories for their mother's murder, see McWilliams, Narr, Goodman, Ruiz, and Mendoza (2013).

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CHAPTER 17

Memory and Aging

As outlined in Chapter 16, the development of memory in infants and children takes time but it gets better. This much is obvious even to the most casual observer. There is also a strong expectation of memory change at the other end of life. Memory is an area of our lives in which we expect to see changes in as we progress into old age. The stereotype is that old people are more forgetful and there is some truth to this. However, the natural aging process does not negatively affect all types of memory. There are some things that stay the same or even improve.

We start this chapter by covering issues involved with testing older adults and the neurological changes that occur during the natural aging process. After this we look at some things that decline and change as people grow older. Because the news is not all bad, we also look at memory processes that stay the same or improve with aging. A more general change in cognition that happens when people grow older is how they process emotions and emotional information. Finally, although they are not caused by aging but are so strongly correlated with advanced age, we consider various dementias and how they influence memory.

TESTING OLDER ADULTS AND NEUROLOGICAL CHANGE

When assessing memory in older adults, some basic issues need to be considered. Two primary ones are how older adults are tested and changes that occur in the nervous system. We consider each of these in turn.

Testing Older Adults

When studying memory in older adults, one issue that must be resolved is how changes in memory are to be assessed. There are two ways to do this. One is to do a **cross-sectional study**, in which a group of older adults is compared with a group of younger adults, typically college students. In these cases, the younger adults are treated as the standard, or control group, against which the older adults are compared. This is the type of study that is most often done in memory and aging research. This is because these studies can be done relatively easily and quickly. Because younger and older adults differ in systematic ways, the results can be enlightening.

However, there are some issues with cross-sectional studies. One thing that is more of an issue for older adults than for younger adults is the variability among people. There is typically far more variability in performance for older adults than for younger adults (Williams, Hultsch, Strauss, Hunter, & Tannock, 2005). As an example, the change in the amount of response time variability across the life span is shown in Figure 17.1. Note that, in the figure, while older adults are more variable than younger adults overall, there are some older adults who are less variable than even most of the younger adults.

Part of this variability simply reflects the range of ages of the people involved. For younger adults, the research participants are often college-aged people, typically from 18 to 22 years old. This is not a very large age range. However, for older adults, the age range is often much broader, involving people anywhere from their early 60s to their 90s. Thus, there is a span of many decades. People at these different ages are not all the same and this increased variability makes it harder to detect changes. Some studies split the older adults into two groups, often called the young-old and the old-old. For example, the young-old might be people from 60–75 and the old-old would be people age 76 and up.

Apart from the wider range of ages tested, there is increased variability even if older adults are limited to a narrow age range. Compared to older adults, younger adults are quite homogeneous. By the time people reach older adulthood, they have had a broader range of experiences and are feeling the impact of multiple decades' worth of life choices; any innate differences have had more time to manifest themselves. As a result, older adults are more likely to show broad differences among one another and this increased variability complicates studies of aging and memory.

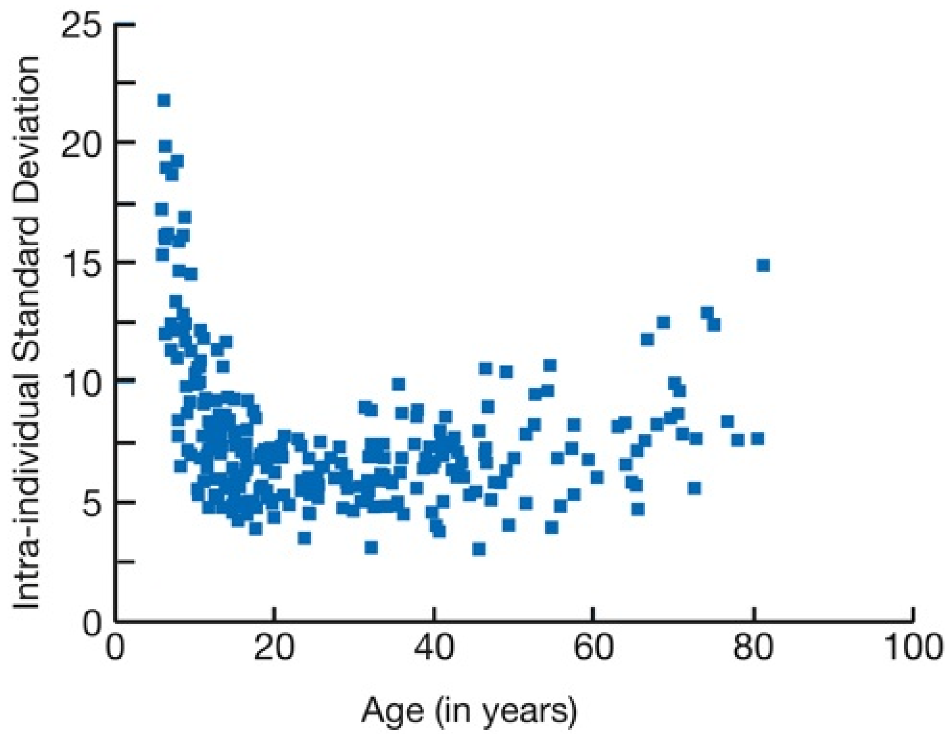

FIGURE 17.1 *Changes in the Amount of Intra-Individual Variability (how Variable a Given Person's Responses Are) for Response Times Across the Life Span*

Source: Williams, B. R., Hultsch, D. F., Strauss, E. H., Hunter, M. A., & Tannock, R. (2005). Inconsistency in reaction time across the life span. *Neuropsychology*, *19*(1), 88–96

One last thing to keep in mind is that the life experiences of people from different age cohorts can be quite different. This is true for the education and social contexts people have experienced. So, researchers need to be mindful that any age differences observed could be due to such causes. Again, given the wide range of ages in groups of older adults, there is more variety of experience for those people than with younger adults.

The other way of assessing age-related changes in memory is do a **longitudinal study**, in which the same individuals are tested at multiple points in time. The advantage of a longitudinal study is that it avoids many of the problems with cross-sectional studies. Because the same people are tested repeatedly, any differences in memory are more likely to be due to age-related changes. This is because people are serving as their own controls. Even with the greater variability among older adults, because you know where each person is starting off at the beginning of the study, researchers can better target age-related memory changes.

There are some insightful longitudinal studies of age-related memory change.

One example is the Betula study of memory, health, and aging done in Sweden (Nilsson et al., 2004). This study, begun in 1988, involves testing a large set of people every five years. At the beginning of the study, participants ranged in age from 35 to 80 years of age. The wide range of ages allows researchers to do both cross-sectional and longitudinal comparisons. One finding from this study is that age-related declines in declarative memory may be overexaggerated in cross-sectional studies. A comparable longitudinal analysis showed smaller deficits (Rönnlund, Nyberg, Bäckman, & Nilsson, 2005).

So, given their advantages, why aren't longitudinal studies done exclusively? Well, there are some difficulties. First, they take a lot of time, money, and effort. Second, it takes a long time to get the data. Memory research is a scientific endeavor and our understanding is constantly changing. If you have a decades-long study, it could be that issues that were thought to be important turn out not to be, or are better measured a different way, and new ways of understanding memory emerge. By the later decades of the study, the data collected from the early years of a longitudinal study might not be as informative or as insightful as a cross-sectional study. Third, there is always an issue of people dropping out of the study as time goes on. The reasons for their dropping out could be important if those people who perform worse do not return to the study. This makes the effects of aging look better than they actually are. A final concern is that the same people are getting the same or similar tasks multiple times. Any experience they have with a task changes how they do later, even if it is years down the road.

Neurological Changes

Age-related neurological change is a universal phenomenon seen across a variety of cultures (Park, Nisbett, & Heeden, 1999). One of the most basic changes that occurs is in the rate or speed of neural firing, which is slower in older adults. As a consequence, older adults take longer to engage in any cognitive process compared to younger adults. This is one reason why your following distance behind cars will likely become larger as you grow older. At some level you are aware that your reflexes are not as fast as they used to be and you implicitly give yourself more time to stop. Thinking more abstractly, the more complex a mental task is, the more noticeable the slowdown. Thus, memory processes that take more time overall are even slower for older adults.

Age-related changes in neural processing have led to theories of memory and aging, known as **speed theories**. These changes can affect memory in many ways. For example, during processing it is more likely that forgetting will occur for some of the information in the stream of thought, and performance declines (Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1996), leading to more problems.

In addition to neural speed, other parts of the brain are changing. The frontal lobes undergo the greatest change (Albert & Kaplan, 1980) and are less effective in older adults (Rypma, Prabhakaran, Desmond, & Gabrieli, 2001). This reduces the ability to control the flow of information in memory. The part of the frontal lobes that is most affected is the dorsolateral prefrontal lobe (on the top and sides in the front) rather than the ventromedial prefrontal lobe (on the bottom and middle) (MacPherson, Phillips, & Sala, 2002). The dorsolateral prefrontal lobe is more responsible for the central executive part of working memory, controlling the flow of thought. In contrast, the ventromedial prefrontal lobe is more involved in emotional and social tasks, such as regulating one's feelings.

The age-related decline in the frontal lobes leads to a decline in the ability to inhibit irrelevant information (Hasher & Zacks, 1989) as captured by **inhibition theory**. When older adults are trying to remember things, related but irrelevant information is activated, thereby clogging the stream of thought. In a sense, one reason that older adults have trouble with memory is not that they are remembering too little but that they are remembering too much.

With aging, there are also problems with the temporal lobes. Related to this are problems with the hippocampus, which shows declines with aging in the ability to engage in LTP (Jessberger & Gage, 2008). As a reminder, LTP is critical for the formation of long-term memories. As such, older adults show global problems with learning and retrieving information.

One way older adults compensate for these declines is to decrease cerebral lateralization (Colcombe, Kramer, Erickson, & Scalf, 2005), in which one hemisphere of the brain (left or right) becomes more dominant or does more of the processing than the other. Lateralization occurs initially because a group of nearby cells can make the necessary computations faster than groups that are spread out and need to pass information along the corpus callosum. However, in older adults there is less lateralization (Cabeza, 2002; Reuter-Lorenz & Cappell, 2008). This may be because older adults need to recruit a larger array of cells to do the same job that a more localized portion would handle in younger adults.

Stop and Review

Aging brings about changes in memory. Most research involves the use of cross-sectional studies in which younger adults, often college students, are compared with older adults. Alternatively, longitudinal studies can be done in which a set of people are assessed repeatedly over time. A primary neurological change with aging is a slower rate of neural firing. More globally, there are declines in portions of the frontal and temporal lobes, which influence the effectiveness of memory function. There is also some degradation of hippocampal functions, such as LTP, which makes the acquisition of some types of knowledge more difficult. Finally, there is decrease in the lateralization of processing as older adults engage in more whole-brain processing.

SOME THINGS CHANGE

According to the stereotype, there are a number of age-related declines in memory. There is some truth to this. This section covers these changes. We start by discussing changes in core memory abilities, such as changes in short-term/working memory, episodic memory, and semantic memory. We then discuss changes in more specialized topic areas.

Core Memory

First off, older adults have reduced **short-term/working memory** capacities (Craik & Byrd, 1982). Because of this, they are less able to coordinate information to the degree necessary for efficient thinking, especially when working memory demands are large. One example of this decline can be seen during text comprehension. In a study by Light and Capps (1986), people heard brief three- to five-sentence stories in which the final sentence contained a pronoun that referred back to a story character. What was manipulated was the distance between the characters and the pronoun by varying the number of sentences between them. The greater the distance, the more performance declined, especially in older adults. An example of some data showing this disruption is given in Table 17.1. Because older adults have less memory capacity, they have a greater difficulty holding on to a name and are more likely to forget it. As a result, when the pronoun is heard they have a harder time determining to whom it refers.

A noticeable age-related change in **episodic memory** is a decline in the ability to recall and recognize information (Zacks, Hasher, & Li, 2000). Part of the difficulty is with binding different types of information together to store complex episodic memories. This could even lead to the binding of irrelevant information into a memory trace (Campbell, Hasher & Thomas, 2010). Thus, certain characteristics of an experience, such as context and features, may not be stored as effectively. As a result, older adults show smaller von Restorff effects (Bireta, Surprenant, & Neath, 2008; but see Gallo, Cotel, Moore, & Schacter, 2007), smaller bizarre imagery effects (Nicolas & Worthen, 2009), smaller encoding specificity effects (Duchek, 1984), and smaller adaptive memory effects (Stillman, Coane, Profaci, Howard, & Howard, 2014).

TABLE 17.1 *Effects of Age-Positive and Age-Negative Words on Memory in Terms of Percentages of Accurate Resolutions of Anaphors: Differences in Pre- and Postexposure Conditions*

	Young	**Old**
Number of intervening sentences		
Zero	65.1	64.1
One	61.8	58.3
Number of intervening sentences		
Zero	64.9	63.4
Two	61.3	54.7

Source: Light & Capps (1986)

For **prospective memory**, there are some declines with old age (Einstein & McDaniel, 1990; Maylor, 1993), depending on the type of prospective memory being considered. Older adults show declines for both time-based and event-based prospective memory, but more so for time-based prospective memory (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997; see Henry, MacLeod, Philips, & Crawford, 2004 for a meta-analysis).

That said, it should be duly noted that older adults tend to do better in naturalistic settings (such as remembering appointments) (Bailey, Henry, Rendell, Phillips, & Kliegel, 2010). This may reflect better time management and the use of strategies that compensate for other declines in prospective memory. For example, time-based prospective memory in older adults is better when they lay out a plan (e.g., taking medication) ahead of time rather than just rehearsing information (Chasteen, Park, & Schwarz, 2001) or if the prospective task occurs with some regularity (Rose, Rendell, McDaniel, Aberle & Kliegel, 2010).

Older adults spend more time thinking proactively than younger adults do (Gardner & Ascoli, 2015). The difficulty older adults have with prospective memory may reflect difficulties self-initiating a memory process as needed (Craik, 1986). Older adults are less able to monitor themselves and so are more likely to not start something, such as a prospective memory task, when it is needed (Albinski, Sedek, & Kliegel, 2012).

Older adults also have trouble regulating the retrieval of information from long-term memory. For example, older adults are more susceptible to associative interference and show larger fan effects than younger adults do (Gerard, Zacks, Hasher, & Radvansky, 1991). They also show smaller retrieval practice effects (Aslan & Bäuml, 2012). Both are consistent with the idea that older adults have difficulty suppressing related and irrelevant information (Healey, Hasher, & Campbell, 2013). So, as older adults are trying to remember something, they experience more interference from related memories, thereby making their retrieval slower and less accurate.

STUDY IN DEPTH

Prospective memory—remembering to do something in the future—can show age-related declines. One illustration of this is a study by Einstein and McDaniel (1990). For this study, they recruited 48 participants. Twenty-four were students at Furman University, who ranged in age from 17 to 24 years old. The rest were alumni of Furman who agreed to participate, ranging in age from 65 to 75. These were community-dwelling older adults who drove themselves to the study.

For the study, people were seated at a computer. The primary task was a short-term memory task in which people were to learn lists of words and report them back. Each list was four to nine words long for the younger adults and three to eight words long for the older adults. There were 42 trials. Each list was drawn from a set of 26 one- and two-syllable words. Thus, the words were repeated during the course of the study. On each trial, people saw a "Prepare for Trial" signal for a second and a half. Then, they saw a list of words shown at a rate of one word every three-quarters of a second. At the end of a list, people were given a "recall" signal, at which they were to verbally report all of the words that they could remember, in the order that they saw them. People were given three minutes for these recall periods. Three additional trials were given as practice to help familiarize people with the task.

The secondary task was the prospective memory task. People were told to press a key on the computer keyboard whenever they heard the word "rake." As such, this is event-based prospective memory. This critical word appeared on three trials. The dependent measure was the rate at which people remembered to press the key in response to seeing this word.

What was found was that older adults remembered to do the prospective memory task less often than the younger adults. On average, younger adults did it 77% of the time, whereas the older adults did it 58% of the time. Thus, the older adults had some prospective memory difficulty.

In terms of directed forgetting, older adults perform less well than younger adults (Andrés, Van der Linden, & Parmentier, 2004; Zacks, Radvansky, & Hasher, 1996; for a meta-analysis see Titz & Verhaeghen, 2010). This is more likely to happen using the item method and selective directed forgetting than for the list method (Aguirre, Gómez-Ariza, Bajo, Andrés, & Mazzoni, 2014; Zellner & Bäuml, 2006). This decline in directed forgetting has been attributed to declines in inhibitory processes (but see Sahakyan, Delaney, & Goodmon, 2008). For example, if later asked to recall items that they were previously told to forget, older adults recall more to-be-forgotten items than younger adults because this information was not sufficiently inhibited.

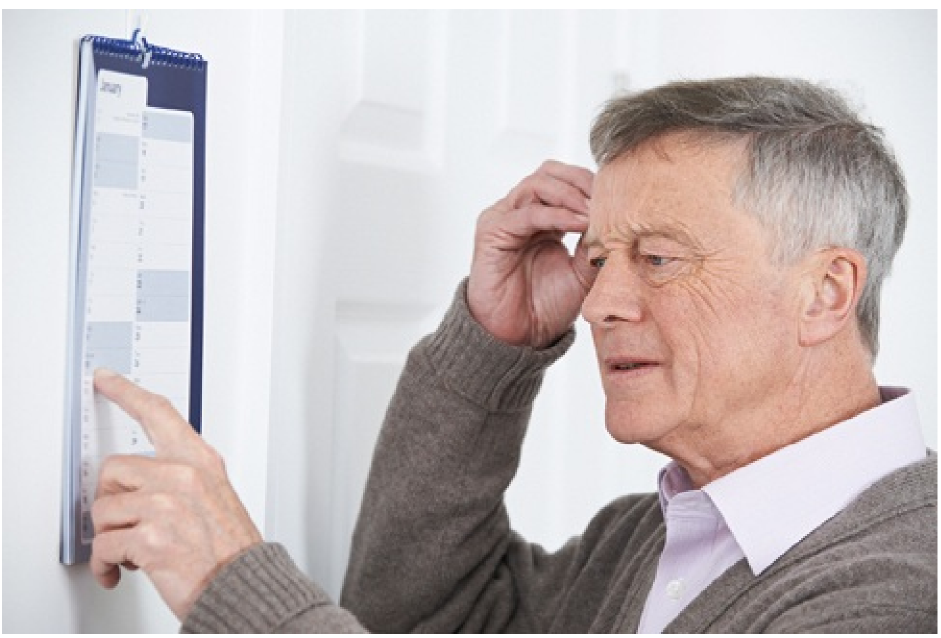

PHOTO 17.1 *Some aspects of memory, such as episodic and prospective memory, can decline with age*

Source: Highwaystarz-Photography/iStock/Thinkstock

Specialized Topic Areas

For **autobiographical memory**, older adults' memories are dominated more by salient landmark events, self-relevant information, and emotionally positive events (Dijkstra & Kaup, 2005). They also become more generic, with fewer details, for both retrospective memories and future thoughts (Addis, Wong, & Schacter, 2008). However, this is more true for deliberate autobiographical memories than for spontaneous ones (Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009), although spontaneous memories are more emotionally positive, overall. Older adults also focus more on the semantic than the episodic aspects of autobiographical memory, and these memories are experienced more from an observer than a field perspective and are more likely to be classified as "known" rather than "recollected."

In terms of **memory and reality**, older adults show several declines. First, older adults are less effective at source monitoring and are more likely to make reality monitoring errors, confusing perceived and imagined events, perhaps because of declines in memory for perceptual and contextual information (Hashtroudi, Johnson, & Chrosniak, 1990). They are also more likely to make destination errors and forget to whom they've told something in the past (causing them to tell the same story multiple times) (Gopie, Craik, & Hasher, 2010). Older adults are also more likely to have source monitoring errors for perceptually similar sources (e.g., two women) (Ferguson, Hashtroudi & Johnson, 1992). Older adults' decreased ability to integrate different types of source information leads to an increased likelihood of exhibiting cryptomnesia (McCabe, Smith, & Parks, 2007) and false fame effects (Dywan & Jacoby, 1990). This can be seen in ERPs recorded during source monitoring, with younger adults' ERP waves showing greater discrimination than older adults' (Dywan, Segalowitz, & Webster, 1998).

As noted later, older adults place more emphasis on semantic memories, such as categories and schemas. As a consequence, they may be more likely to report general knowledge-based false memories, such as the DRM false memory effect (see Chapter 12) (Norman & Schacter, 1997). This increase in false memory reports can be attributed to declines in the ability to monitor reality, as well as changes in inhibitory processing. Both of these changes reflect declines in overall frontal lobe functioning (Butler, McDaniel, Dornberg, Price, & Roediger 2004; Dehon & Brédart, 2004; but see Chan & McDermott, 2007).

In addition, older adults are more likely to create false event memories (Gallo & Roediger, 2003), which may involve script-consistent information that was not actually encountered (LaVoie & Malmstrom, 1998). Older adults are also more likely to misidentify positive attributes as corresponding to the choices they selected (Mather & Johnson, 2000). Some of the increase in false memories is due to older adults being less able to use conscious-based recollections of prior events and relying more on familiarity (Jacoby & Rhodes, 2006). That said, it should also be noted that age-related changes in source monitoring do not always occur. When two sources are defined based on value characteristics, such as being told that John always tells the truth and Mary always tells lies, older and younger adults do equally well at identifying the source of a memory (Rahhal, May, & Hasher, 2002).

For issues related to **memory and the law**, it has been found that older adults are just as likely as younger adults to have memory influenced by misleading postevent suggestions. However, older adults are more confident in these memory errors (Dodson & Krueger, 2006). Again, these misinformation errors may be caused by source monitoring problems. For example, older adults are more likely to pick a person from a police lineup even if the person was not the perpetrator but had only been seen in a series of mug shots (Memon, Hope, Bartlett, & Bull, 2002).

There are a number of age-related changes in **metamemory**. Older adults are less accurate in their judgments of learning (JOLs) than younger adults (Bieman-Copland & Charness, 1994), which may be due to declines in conscious recollection processes (Daniels, Toth, & Hertzog, 2009). Thus, older adults are less able to assess whether they have in fact learned something. However, older adults do effectively use relative accuracy and their use of JOLs to guide their study time (Dunlosky & Hertzog, 2000; Miles, & Stine-Morrow, 2004). They adjust their JOLs based on the nature of the information being learned, such as whether it is difficult or easy.

Another difficulty that older adults have with metamemory is with feeling-of-knowing (FOK) judgments. Older adults' FOK ratings are generally poorer than younger adults', although primarily for episodic, but not semantic, knowledge (Souchey, Isingrini, & Espagnet, 2000) and they may experience greater problems in a tip-of-the-tongue state (White & Abrams, 2002) and the hindsight bias (Groß & Bayen, 2015). Relatedly, older adults are more confident in their recognition errors, which rely more on levels of familiarity than on explicit recollection. This could be due to declines in medial temporal lobe activity and their increased reliance on overall cortical activity (Chua, Schacter, & Sperling, 2009). Overall, older adults show declines in conscious recollective experiences but with no declines in more unconscious familiarity-based memory (Prull, Crandall Dawes, McLeish Martin, Rosenberg, & Light, 2006).

Up to now, we have seen that older adults have some trouble with memory. However, memory does not inevitably get worse. In the next section we highlight some things that stay the same or even improve. Before that, it is important to understand that one's attitude has a strong influence on how memory performs. If a person *thinks* that memory gets worse with age, then performance will be worse (Hess, Auman, Colcombe, & Rahhal, 2003; see Lamont, Swift, & Abrams, 2015, for a meta-analysis). This occurs at a subconscious level. In a study by Levy (1996), older adults were given a series of memory tests. Prior to this they were subliminally exposed to a number of age-positive words, such as "wisdom," "sage," or "guidance," or age-negative words, such as "senile," "dementia," and "decrepit." Although the older adults were not aware that they had seen the words, their performance was affected. Data from this study is shown in Table 17.2. Older adults did worse following age-negative words but better following age-positive words. There was no such influence for the younger adults. Thus, the implicit age-related stereotypes that are activated can impact on how well memory actually works.

When goals are set for people to improve memory, both younger and older adults respond well, and this is sometimes greater for the older adults (West, Thorn, & Bagwell, 2003), although not always (Chasteen, Bhattacharyya, Horhota, Tam, & Hasher, 2005). This suggests that older adults may be more prone to discounting their abilities and may be making their situation worse by having self-handicapping thoughts.

TABLE 17.2 *Effects of Age-Positive and Age-Negative Words on Memory: Difference in Pre-and Postexposure Conditions*

	Older Adults		**Younger Adults**	
	Negative	***Positive***	***Negative***	***Positive***
Immediate recall	−1.77	0.98	−0.36	−0.10
Learned recall	−0.46	0.49	0.43	0.07
Delayed recall	−1.11	0.20	0.33	−0.07
Photo recall	0.14	1.50	0.77	0.24
Auditory recall	−0.64	–0.20	−0.47	−0.60

Source: Levy (1996)

Stop and Review

A common idea is that memory gets worse as we grow older. There is a decline in short-term/working memory capacity, with older adults less able to keep as much information active. There are also declines in episodic memory, which older adults find harder to form. Older adults also have trouble with prospective memory, although these effects are larger in the laboratory that in everyday life. In terms of forgetting, older adults are less able to regulate interference at retrieval, possibly due to a decline in inhibitory processes. Relatedly, older adults are not as efficient at some types of directed forgetting. For autobiographical memory, older adults report fewer details and tend to focus on positive events. For memory and reality, older adults are more prone to false memories and are more confident in their memory errors. Finally, older adults are less aware of their own memory contents and processes than younger adults are. Many of these age-related deficits are worsened by negative social stereotypes about aging and memory.

SOME THINGS STAY THE SAME

While aging is associated with declines in memory, there are some aspects that remain constant and even improve. This follows on ideas outlined by Hess (2005) that note that traditional views of memory and aging may overemphasize age-related declines, miss areas of stability or improvement, and do not take into account adaptive developmental changes, and that there is a greater degree of variability between people when older adults are considered.

Core Memory

There are a number of aspects of memory that are not negatively affected by the natural aging process. **Nondeclarative memories** show some stability with age, perhaps because they are neurologically more robust. For example, other than an overall change in processing speed, there is little in the way of age-related changes in priming (Fleishman, Wilson, Gabrieli, Bienias, & Bennett, 2004). Similarly, procedural skills, such as golf putting, as shown in Figure 17.2, are learned similarly at nondeclarative memory level by younger and older adults (Chauvel, Maquestiaux, Hartley, Joubert, Didierjean, & Masters, 2012). Thus, motor skills that are acquired earlier in life can remain largely intact into old age.

As noted in the previous section, there is no doubt that **episodic memory** declines with age. However, this decline has limits. Some aspects of episodic memory stay at a high level and may even improve. The distinction between what is and is not remembered is a distinction between quantitative and qualitative aspects of memory (Small, Dixon, Hultsch, & Hertzog, 1999). There is a near-uniform quantitative decline in episodic memory, with older adults remembering less. However, qualitative aspects of memory are preserved. That is, the way information is remembered stays the same. Older adults show as much information organization and structure during remembering as do younger adults and may even show an increase (Kahana & Wingfield, 2000).

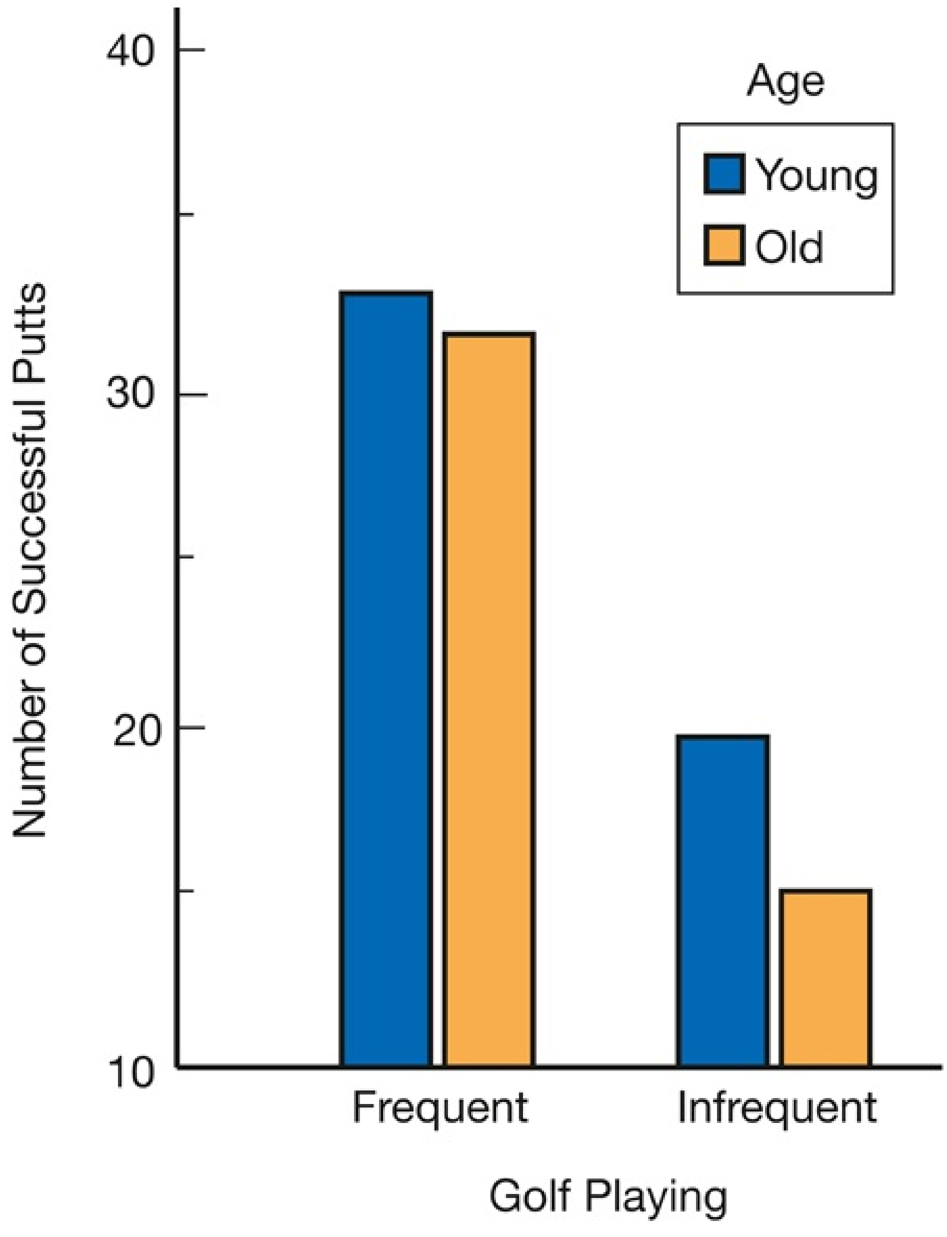

FIGURE 17.2 *Data for Golf Putting Success Showing That Older Adults Who Maintain Their Skill (Frequent Golfers) Show no Skill Deficit Compared to*

Younger Adults

Adapted from: Chauvel, G., Maquestiaux, F., Hartley, A. A., Joubert, S., Didierjean, A., & Masters, R. S. (2012). Age effects shrink when motor learning is predominantly supported by nondeclarative, automatic memory processes: Evidence from golf putting. *Quarterly Journal of Experimental Psychology*, *65*(1), 25–38

Older adults have preserved abilities to update their understandings. They are as likely to forget information after walking through a doorway as younger adults are (Radvansky, Pettijohn, & Kim, 2015). This more fundamental type of knowledge (as compared to words) may remain robust during the course of development. Older adults are also better able than younger adults to forget and modify their understanding when they get something wrong (Metcalfe, Casal-Roscum, Radin, & Friedman, 2015). They are less likely to be misled by information that they encounter that is inconsistent with their world knowledge (Umanath & Marsh, 2012).

Although older adults show some declines in inhibitory processes during memory retrieval, they do not show declines in the suppression of irrelevant concepts in the retrieval practice paradigm (Aslan, Bäuml, & Pastötter, 2007). This suggests that not all types of inhibitory processes are compromised in old age. Similarly, the greater dependency older adults have on the organization of information in memory, may lead them to be more susceptible to things such as part-set cuing (Marsh, Dolan, Balota, & Roediger, 2004). This organizational dependency is also revealed in the finding that, like younger adults, older adults are similarly likely to forget information when recalling in groups, in which one's retrieval plan is disrupted (Henkel & Rajaram, 2011).

One of the biggest areas of stability and improvement for older adults is with **semantic memory** (Rönnlund et al., 2005). Over a lifespan, people are exposed to a broad range of information, and this knowledge continues to accumulate. Older adults often outperform younger adults on measures of semantic knowledge, such as vocabulary tests. This is not related to educational factors, such as the older adults getting a "better" education. Moreover, the structure of semantic memory is largely unchanged, as evidenced by the finding that semantic priming effects remain stable (Balota & Duchek, 1988; Lavaer & Burke, 1993), including both automatic (Howard, McAndrews, & Lasaga, 1981), more consciously controlled priming (Burke, White, & Diaz, 1987) and even mediated priming (Bennett & McEvoy, 1999). Older adults can reliably draw on a broader range of real-world knowledge than younger adults can.

Because of the preservation and expansion of semantic memory for older adults, as episodic memory declines there is a greater reliance on information in semantic memory, such as schemas and scripts (Arbuckle, Vanderleck, Harsany,

& Lapidus, 1990; Light & Anderson, 1983; Umanath & Marsh, 2014). Thus, older adults focus on more important (relative to less important) information (Castel, Farb, & Craik, 2007). Older adults rely on their schemas so much that they may have more trouble suppressing them when they are irrelevant (Arbuckle, Cooney, Milne, & Melchior, 1994).

As noted earlier, the information that is more readily forgotten, and most likely to suffer as a consequence of aging, is memory for details. Keeping in mind fuzzy trace theories, memory is composed of detailed, specific memories and more general, gist-related memories. As the aging process proceeds, episodic memory declines but semantic memory improves. As a result, older adults' memories are more likely to be influenced by general information than by memory for details (Koutstaal, 2006; Koutstaal & Schacter, 1997; Reder, Wible, & Martin, 1986), which is not observed when older adults do not have prior knowledge (Koutstaal, Reddy, Jackson, Prince, Cendan, & Schacter, 2003).

This differential emphasis on semantic and episodic memory is also seen with social judgments. Older adults are more likely to make predictions of other people's future behavior based on a general, schematic understanding than on specific episodic information about the person (Hess, Follett, & McGee, 1998). However, not all social judgments are biased toward schematic information. If people are asked to rate how likable a person is, younger and older adults use schematic and specific information similarly (Hess & Bolstad, 1998). Thus, while older adults are more dependent on their semantic knowledge, they can disregard it when needed.

The stability and reliance on semantic knowledge can lead it to be activated and used, even though we don't want it to be, as is the case with social stereotypes. Older adults are in a position in which their semantic knowledge is intact but their ability to suppress unwanted information is compromised. As a consequence, older adults are more likely to activate stereotypes and be influenced by them, even when they are trying to be egalitarian (Radvansky, Copeland, & von Hippel, 2010; Stewart, von Hippel, & Radvansky, 2009). Thus, older adults may, at times, be prejudiced against their will. That said, it is also possible for older adults to deactivate stereotypes if they are discounted in some way (such as explicitly noting that a babysitter was male) (Radvansky, Lynchard, & von Hippel, 2009).

PHOTO 17.2 *Some aspects of memory, such as semantic memory and higher-order memories, are preserved, or even improve, with age*

Source: LittleBee80/iStock/Thinkstock

Specialized Topic Areas

Another area of memory that is less affected by aging is **higher-level memory**, such as the mental model level (Radvansky & Dijkstra, 2007). Younger and older adults use mental models similarly in memory (Radvansky, Gerard, Zacks, & Hasher, 1990). In some cases, while older adults show memory problems at other levels, such as remembering verbatim or propositional information, their ability to remember information at the mental model level is unaffected (Radvansky, Zwaan, Curiel, & Copeland, 2001). This preserved memory is seen in everyday tasks, such as remembering news events (Frieske & Park, 1999). Compared to younger adults, older adults remember the content of news stories and the sources of those stories better. Relatedly, older adults and younger adults show similar flashbulb memory effects (Berntsen & Rubin, 2006; Kvavilashvili, Mirani, Schlagman, Erskine, & Kornbrot, 2010).

There are also age-related changes in **metamemory**. Not only do older adults have generally superior semantic memories; they also have a greater awareness of this expanded knowledge base (Kavé & Halamish, 2015). When learning new things, they appear to rely on the region of proximal learning as much as younger adults do (Price & Murray, 2012). On another topic, Bayen, Erdfelder, Bearden, and Lozito (2006) found no major effect of aging on the hindsight bias (see Figure 16.6). Hindsight judgments are similar in younger and older adults.

Aging and Emotion

Overall, older adults showed an enhanced ability to regulate their emotions (Urry & Gross, 2010). They also more often show mood congruency effects in memory (Knight, Maines, & Robinson, 2002). Although older adults are less efficient than younger adults at source monitoring and some prospective memory tasks, these age differences disappear if the information is emotional (May, Rahhal, Berry, & Leighton, 2005). A similar age-invariant finding is observed for emotional information in working memory, particularly for positive materials (Mikels, Larkin, Reuter-Lorenz, & Carstensen, 2005). It should be noted that this emotion influence is only observed if a person is thinking about the emotional aspects of an event at the time. It does not occur automatically (Emery & Hess, 2008).

Improving Your Memory

Some parts of memory remain stable or improve with age. Is there anything that you can do to make it more likely that you will be one of those people who show less of a mental decline? In short, the answer is, to some degree, "yes." Hertzog, Kramer, Wilson, and Lindenberger (2008) outlined a number of steps that you can take to address age-related changes in memory and keep any deficits to a minimum. They cover the intellectual, social, and physical activities a person can engage in to aid memory. In short, the more that you stay active in a number of complex intellectual, social, and physical activities, the more successfully you will age and the smaller your deficits will be. So, be active in a wide variety of things throughout your life and you will have fewer problems as you grow older.

On top of this, the broader your knowledge base is when you enter old age, the more that you will have to work with. So, to put yourself in the best position, expose yourself to as many different experiences as you can. Read a wide variety of books, watch lots of different kinds of shows and movies, go out to plays and concerts, go see different places, and so on. People who are intellectually active throughout their lives (college professors, for example) show smaller or no memory deficits in some areas (Shimamura, Berry, Mangels, Rusting, & Jurica, 1995).

Specifically, with old age there is a tendency to emphasize positive over negative information (Mather & Knight, 2005; Reed & Carstensen, 2012; but see Murphy & Isaacowitz, 2008). This reflects a greater interest in close interpersonal relationships and a desire to control emotions as one ages. As a consequence, older adults show poorer memory for negative information than younger adults do (Charles, Mather, & Carstensen, 2003; but see Gruhn, Smith & Baltes, 2005). This is consistent with fMRI work that shows that, while there are preserved connections between the dorsolateral prefrontal cortex (BAs 9 and 46) and the amygdala, preserving emotional control, the connections from the amygdala to the hippocampus are weakened, suggesting a decline in emotional influences on memory (St. Jacques, Dolcos, & Cabeza, 2009).

Stop and Review

There are areas where memory remains intact or improves with old age. Nondeclarative memories remain largely intact, so long as skills are practiced. For episodic memory, there are declines in the quantity of what is remembered but the quality of those memories improves. Older adults also update their memories as efficiently as younger adults. Perhaps the biggest area in which memory is preserved or improves with aging is semantic memory. Older adults have better vocabularies, schemas, and scripts than younger adults. This may lead older adults to depend more on their semantic knowledge to compensate for deficits they experience in episodic memory. Finally, older adults have more emotional control than younger adults and place a greater premium on positive experiences.

DEMENTIA

Dementia is a condition in which there are serious impairments in many aspects of thinking, only one of which is memory, but without an impairment of consciousness. People often think of dementias as illnesses of the elderly. However, dementia is not caused by the natural aging process. It is true that while many older adults will acquire some form of dementia (11% over the age of 65 and 32% over the age of 85), many younger people contract these diseases as well (Brandt & Rich, 1995). However, because it often emerges with advanced age, it is covered in this chapter. The memory problems that occur with dementia include a decline in the ability to learn new information and a loss of prior memories. Because of widespread brain degradation, this memory loss can even extend to well-ingrained memories. In this section we consider a number of the more prominent dementias. These include Alzheimer's disease, Parkinson's disease, Huntington's disease, and the dementia associated with multiple sclerosis.

Alzheimer's Disease

Alzheimer's disease was first described by Alois Alzheimer in 1907. It is one of the most rapidly expanding health concerns that we have. As the population ages, more people will succumb to its effects. This disease occurs only in certain people as a result of specific neurological conditions. It is not a natural consequence of growing old. While far too many older adults will contract Alzheimer's, most will not.

Alzheimer's disease is a cortical dementia marked by severe degradation in brain structure and function. In essence, with Alzheimer's disease the mind and memory deteriorate. Three primary changes occur (Hodges, 2000). The first is a loss in the number of neurons and neural connections, primarily focused in the frontal and temporal lobes, which are critical for effective memory, with the primarily sensory and motor areas being better preserved. Second, there are **neurofibrillary tangles** that occur within neurons and impede their ability to effectively transmit a signal. They grow over time, eventually pushing other neural structures, such as the nucleus, mitochondria, and ribosomes, to one side, disrupting their function, and filling up the interior of the axons and dendrites. Finally, a third change is the presence of **amyloid plaques**, which are growths of old neural tissue with a core of amyloid proteins that occupy the regions around neurons and are surrounded by microglia. These plaques are about 70 microns in diameter, much larger than the neurons, which are often only 10 to 30 microns in diameter. Their presence makes it difficult for neurons to function because they degenerate the neurons' axons.

In addition, with Alzheimer's disease there are also changes in the cholinergic system (Bartus, Dean, Beer, & Lippa, 1982), particularly the manufacturing of the neurotransmitter acetylcholine (ACh), which is critical to learning and memory. The decrease can be mediated somewhat by people taking an ever-increasing list of medications that have been found to positively affect the symptoms of this disease.

No one knows for sure exactly what causes Alzheimer's. However, a number of preconditions are known that indicate the likelihood of contracting the disease

(Small, 1998). There is a strong genetic component. If a relative has Alzheimer's, there is a 25% to 50% probability that a person will develop it as well. If not, then the probability is only 10%. In identical twins, if one twin contracts the condition, there is a 40% to 50% chance that the other will as well, and a 10% to 50% chance for fraternal twins. There is a higher rate of occurrence of the disease in people with Down syndrome, also suggesting a genetic component.

There are also external, environmental influences. For example, people who have suffered head traumas or long periods of depression are more likely to succumb. There are some protective factors. People who have been exposed to estrogen or antioxidants may be less likely to get the disease. Similarly, people who experience body inflammations, such as arthritis, are less likely to contract Alzheimer's. There may also be some DNA combinations that are more resistant to this condition. Thus, there are many factors that impact whether a person will one day have to live with Alzheimer's disease.

People with Alzheimer's disease suffer from working memory problems. These tend not to be problems maintaining information but with controlling the flow of thought in the central executive. They have normal working memory spans for verbal and spatial information. However, they do not show normal recency effects for larger sets of information. In terms of central executive problems, they have trouble managing memories under dual task conditions, where a person needs to keep track of two things at once. As such, they can become more easily confused and overwhelmed.

Alzheimer's disease has a profound effect on episodic memories, although there is a temporal gradient, with newer memories being more likely to be compromised than older memories (e.g., Sadek et al., 2004). This temporal gradient of memory loss can be extensive, reaching back several decades. As the disease progresses, there are losses of earlier and earlier memories, which can result in changes and losses in a person's identity (Addis & Tippett, 2004). The temporal gradient of memory loss suggests that a factor in this condition is in encoding. It is even difficult for Alzheimer's patients to form new flashbulb memories (Budson & Gold, 2009). Neurological work using fMRI scanning has shown that the prefrontal lobes of Alzheimer's patients are not functioning as well as normal people's (Corkin, 1998). The rate with which they forget episodic information, once it has been encoded, is the same as for people without the disease (White & Ruske, 2002). Thus, the episodic memory problems can be viewed as a form of anterograde amnesia (see Chapter 18). Retrieval, while difficult, is less of a problem, at least in the earlier stages of the disease. This deficit is more profound with recall than with recognition.

Although semantic memory is initially more resistant, it does eventually succumb. Alzheimer's disease patients may lose the ability to recall the names of objects and may substitute similar words—for example, using "tiger" or "animal" for "lion." Thus, there is a degree of noise and error in semantic memory. This can also be seen in how semantic memories are lost. Memory of how something is used to interact with other objects—that is, its functional relations—is lost sooner than knowledge about its parts and properties, with knowledge about categorical relations being the most resistant (Johnson & Hermann, 1995). Also, with regard to semantic memory, these people have trouble processing new semantic categories (Nosofsky, Denton, Zaki, Muphy-Knudsen, & Unverzagt, 2012). Patients with Alzheimer's disease are more likely to have trouble remembering public information than autobiographical information (Greene & Hodges, 1996). Here is a case where stable, semantic information is more vulnerable than episodic information.

Although many memory systems are affected by Alzheimer's disease, some systems are less affected than others. For example, implicit memory processes are more intact. This also spills over into related metamemory processes. Using the remember–know distinction, Alzheimer's disease patients show declines in memory for information that is marked as "remember" but not when it is marked as "know" (Barba, 1997). Also, Alzheimer's disease patients have trouble making accurate source monitoring decisions (Mammarella & Fairfield, 2006). That said, some implicit memory processes are disrupted. For example, Alzheimer's disease patients often show impaired semantic priming.

Parkinson's Disease

The diseases we look at next—Parkinson's, Huntington's, and multiple sclerosis—are subcortical dementias. This is in contrast to Alzheimer's disease, which is a cortical dementia. It should be noted that not everyone who contracts these other diseases become clearly demented. These subcortical dementias are often associated with move ment difficulties, as well as with more minor problems in memory and thinking.

With **Parkinson's disease** there is damage to or loss of neurons in the basal ganglia and the substantia nigra. This is accompanied by a disruption in dopamine processing. This damage produces problems in coordinating movements, such as tremors, "pill rolling" (rubbing fingers together as if rolling a pill), problems in facial expression, and difficulty in walking. Parkinson's disease usually begins around the age of 50. In addition to the movement problems, there are cognitive and emotional deficits, including problems with memory (Brandt & Rich, 1995; Ivory, Knight, Longmore, & Caradoc-Davies, 1999; Prizzolo, Hansch, Mortimer, Webster, & Kuskowski, 1982). There may be working memory problems, such as with updating spatial information in the visuospatial sketchpad. For example, when people with Parkinson's travel through a new space with twists and turns, they may become more disoriented (Montgomery et al., 1993). In addition, they may experience problems identifying locations of previously seen pictures on a simple display grid (Pillon et al., 1997). They do not keep track of spatial contextual information like normal people would.

In addition, people with Parkinson's may have central executive and episodic buffer troubles (Altgassen, Phillips, Kopp, & Kliegel, 2007; Brown & Marsden, 1988). In fact, the visuospatial deficits may actually be a result of more central executive and episodic buffer problems (Altgassen et al., 2007). They have some difficulty controlling their stream of thought and how they use memories. For example, they have difficulty changing strategies and will continue doing things the way they've always done them before (Canavan et al., 1989). They also have difficulty evaluating the importance of events in a semantic schema or script, although they can order scripted information quite well (Zalla et al., 2000).

Like Alzheimer's disease, with Parkinson's disease the loss of episodic memories follows a temporal gradient, with older memories being better preserved than newer ones. However, the extent of the temporal gradient is far more subtle and is not as noticeable. Finally, while the forgetting of event content is less compromised in Parkinson's disease than in Alzheimer's disease, the opposite is true for event date memories. People with Parkinson's disease may have difficulty locating events in time (Sagar, Cohen, Sullivan, Corkin, & Growdon, 1988) or putting information in a correct sequence, such as with a telephone number. There is some suggestion that part of the problem is trouble in coordinating retrieval strategies and not so much with encoding or consolidation (Godbout & Doyon, 2000). Specifically, when recalling the components of a common script, such as going to the doctor, Parkinson's disease patients are more likely to leave out minor components, retrieve script components in the incorrect order, and have more irrelevant intrusions.

Huntington's Disease

Huntington's disease is characterized by uncontrolled muscle spasms, resulting in jerky movements. It is caused by damage to the basal ganglia and the caudate nucleus. It often strikes around the age of 40 and the victim generally dies by the age of 60. In addition, there are problems in memory (Brandt & Rich, 1995).

Huntington's patients have problems with the central executive of working memory, resulting in a reduced memory span and difficulties in dual task situations (Hodges, 2000). However, the rate of forgetting in episodic memory may be preserved along with recognition memory. Also, importantly, there is no temporal gradient to forgetting but it is more uniform across time (Sadek et al., 2004). This suggests that the problem is with retrieval rather than the encoding and storage of memories.

With Huntington's disease, there may be problems with free recall but not recognition, which is consistent with the idea that patients are having trouble planning how to retrieve information. In general, the memory deficits are milder and similar to those observed with Parkinson's. However, they are more likely to have trouble with nonverbal information, such as memory for faces, spatial layouts, or visual images. In the earlier stages of Huntington's disease, patients may be aware of the memory problems they are experiencing but, as the disease progresses, this awareness slips away (De Langavant et al., 2013). Finally, these people may have trouble with procedural memory, even though this memory system is often preserved in people with neurologically related memory losses.

Multiple Sclerosis

Multiple sclerosis (MS) involves a demyelinization of various neurons. Although MS is generally associated with muscle control problems, it can also affect memory. There appears to be some atrophy of cells in area CA1 of the hippocampus, which is important for the creation of declarative memories, as well as damage to portions of the frontal lobe, which is important for controlling the processing of information in memory (Benedict et al., 2002; Sicotte et al., 2008). One of the larger areas of impact is short-term memory. There are problems in both creating and retrieving memories (Pelosi, Geesken, Holly, Hayward, & Blumhardt, 1997) but MS patients appear to have good awareness of their memory deficits (Randolph, Arnett, & Higginson, 2001). There is also a decline in the speed with which short-term memory is scanned, but not so much in working memory capacity (Janculjak, Mubrin, Brinar, & Spilich, 2002). Again, there is a greater disturbance of explicit over implicit memory. Finally, there is some evidence that MS patients have trouble with the retrieval of autobiographical memories (Ernst et al., 2015). So, there can be memory deficits associated with MS.

Stop and Review

Memory can be devastatingly altered by dementia. Alzheimer's disease, the most common form of dementia, results in memory being systematically destroyed as drastic changes are made in the cortex. Other conditions, such as Parkinson's disease, Huntington's disease, and multiple sclerosis, are subcortical diseases that can each have a memory loss component to them. How each condition affects memory depends on the brain structures that are damaged. For example, while Alzheimer's and Parkinson's diseases have memory losses that exhibit a temporal gradient, suggesting a problem in consolidation, Huntington's disease has a flat memory loss gradient, suggesting a problem in memory retrieval.

PUTTING IT ALL TOGETHER

Aging is a time of memory gains and memory losses. How well people do as they age is revealed by cross-sectional and longitudinal studies. As you age, many of your nondeclarative skills will hang around, and may even improve, with practice. The expansion of world knowledge in semantic memory that you are building up will help you better organize your experiences in your memory. This is the source of wisdom that comes with old age. When processing event information, as an older adult you will be better able comprehend, draw inferences, and remember their experiences at higher, abstract levels of thinking. Finally, as an older adult you will be better able to regulate your emotions. Part of this emotion regulation is guided toward placing a greater emphasis on emotionally positive information and experiences, which is known as the positivity effect. This is in contrast to younger adults, who place a greater emphasis on negative information and experiences.

The gains you make as you progress through life can be used to compensate for the losses that you will experience. For example, your neurons won't fire as rapidly as they do now. There also will be neurological changes in your frontal lobes, which are involved in the control of thought and action. This may explain the problems with the control of memory that you experience as you age, with short-term/working memory shrinkage, and with prospective memory and directed forgetting. This also drives some of the loss in inhibitory processes, which can lead to problems dealing with retrieval interference, such as fan effects. Frontal lobe changes are also associated with source memory problems, which can cause difficulties in legal settings. In addition, there are changes in the temporal lobes and the hippocampus, which are important for the acquisition of new memories. As a result, it will also be less likely that you will retain the details of events in episodic memory. This can lead you to be more dependent on your semantic memories, such as schemas, scripts, and stereotypes, as well as feelings of familiarity rather than conscious recollection.

The biggest changes in memory that can occur are if you are unfortunate enough to contract some form of dementia. This is most likely to be Alzheimer's disease, a cortical dementia in which there is a decline in the number of neural connections, the presence of neurofibrillary tangles within neurons, and amyloid plaques outside of and around neurons. As this disease progresses, memory and thinking are compromised. You may also be afflicted with a subcortical dementia, such as Parkinson's disease, Huntington's disease, and multiple sclerosis.

STUDY QUESTIONS

1. What are some of the advantages and disadvantages of studying aging and memory using cross-sectional studies?
2. What are some of the advantages and disadvantages of studying aging and memory using longitudinal studies?
3. What are some major neurological changes that occur with old age that can affect memory?
4. What are the dominant theories of age-related changes in memory? In what ways do they overlap? In what ways are they different?
5. How are short-term/working memory abilities affected by the natural aging process? What are the implications of these changes?
6. What aspects of episodic memory become worse as a person ages? Think about this in terms of both retrospective and prospective memory abilities.
7. What changes in long-term memory occur that cause older adults to be more likely to forget information? How effective are older adults at deliberately forgetting things?
8. How does aging affect autobiographical memories in older adults?
9. How are issues related to memory and reality influenced by aging and what implications does this have for legal settings?
10. What problems do older adults experience with regard to metamemory processing?
11. What role do social attitudes and stereotypes play in age-related problems with memory?
12. What influence does the natural aging process have on nondeclarative memories?
13. What aspects of episodic memory remain intact into old age?

14. Why does semantic memory improve for older adults and how does this increase in semantic memory influence other kinds of memory processes?
15. How is higher-level processing and memory affected by old age?
16. What are the changes in emotional processing that occur with aging? What are the impacts of these changes on aging and memory?
17. What can you do to help preserve your memory ability when you move into old age?
18. What are the characteristics of Alzheimer's disease? What parts of the brain are affected? How is memory affected?
19. What are some of the subcortical dementias? What parts of the brain are affected? How is memory affected?

KEY TERMS

- Alzheimer's disease
- amyloid plaques
- cross-sectional study
- dementia
- Huntington's disease
- inhibition theory
- longitudinal study
- multiple sclerosis (MS)
- neurofibrillary tangles
- Parkinson's disease
- speed theories

EXPLORE MORE

Here are some additional readings for you to further explore issues related to memory and aging.

Chasteen, A. L., Bhattacharyya, S., Horhota, M., Tam, R., & Hasher, L. (2005). How feelings of stereotype threat influence older adults' memory performance. *Experimental Aging Research*, *31*(3), 235–260.

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CHAPTER 18

Forms of Amnesia

As we have seen, one of the most important issues in memory is not how much people remember but how much they forget. In this chapter we consider forgetting on a grand scale, to the extent that it is pathological. **Amnesia** is the catastrophic loss of memories or memory abilities beyond what is expected with normal forgetting, along with otherwise normal intelligence and attention span (O'Connor, Verfaellie, & Cermak, 1995). There are various types of amnesia (Kopelman, 2002). While they vary in their scope and content, they all cripple memory in systematic ways, damaging some memories but leaving others more intact.

Most amnesias are a result of organic brain damage. We begin our coverage by going over two of the more common forms of **organic amnesia**, namely retrograde and anterograde amnesia, which are losses of memories either prior to or after a traumatic brain injury event. We also discuss the transitory loss of memory abilities with transient global amnesia. After that we consider the loss of specific memory abilities, as with semantic amnesia, aphasia, and conditions of this sort. Finally, we cover cases in which there is loss of short-term, rather than long-term, memory function. While most amnesias have an organic origin, some may be a result of a psychological trauma, called psychogenic amnesias. In such cases, the loss of memory may be due to mental trauma and not a problem with the underlying neurophysiology per se.

RETROGRADE AMNESIA

Retrograde amnesia is a loss of long-term memories prior to a traumatic incident, backward in time. In contrast, anterograde amnesia is a loss of the ability to store new long-term memories, forward in time. Although we consider them separately, it is rare to find a pure case of one or the other; typically, both are present to some degree. Some traumas result in much more retrograde than anterograde amnesia, whereas others have the opposite effect. The conditions described here are situations in which one type of amnesia is dominant.

Retrograde amnesia is a loss in the ability to access long-term memories that were previously available (Kapur, 1999). Typically, with retrograde amnesia, the personal past is lost. This is the sort of amnesia that people in soap operas tend to get. Usually, in those scenarios, people get hit on the head and then they can't remember who they are, where they are, whether they're married, and so on. In real life, the situation is more complex and retrograde amnesia has specific defining characteristics.

There are a number of things that can cause retrograde amnesia, and each involves trauma to the brain that disrupts the **consolidation** (see Chapter 2) of long-term memories (McGaugh, 1966; but see Riccio, Millin, & Gisquet-Verrier, 2003). Consolidation is a slow process that makes memories more and more permanent. The easiest memories to disrupt are those that are less consolidated. In severe cases, more stable memories might be disrupted. This may occur when there has been a disruption either to the parts of the brain where the information is held or to the neural mechanisms that are used to retrieve and reconstruct that knowledge.

What can bring about retrograde amnesia? Severe blows to the head are a common cause (and are consistent with accounts provided by the entertainment industry). This physical trauma can affect the brain in a number of ways depending on the nature of the blow, such as its location and intensity. Another cause is a cardiovascular incident, such as a stroke. During a stroke there is a disruption of oxygen and nutrients to parts of the brain. If this disruption is brief, many cells will recover and the memory loss will be temporary. However, with longer periods of time, it is more likely that permanent cell damage and death will occur. With cell death, the patterns of neural information are disrupted and there is a permanent memory loss. This is why stroke victims may need to relearn how to speak and walk.

Ribot's Gradient

One characteristic of retrograde amnesia is a graded loss of memory, in which more recent memories are more easily disrupted. In contrast, older memories are more firmly established and difficult to disrupt. This graded pattern of memory loss and retention is **Ribot's gradient** (Ribot, 1882)[1] and it reflects the consolidation of memories in the nervous system. Memory loss is greater as the age of the memory approaches the time of the incident. Basically, the older a memory is, the more consolidated it is and the less susceptible it is to disruption (Brown, 2002).

At first glance, Ribot's gradient seems to be the opposite of Ebbinghaus's retention curve. As a reminder, from Chapter 3, with the Ebbinghaus curve, the older a memory is, the more likely it is forgotten. In contrast, with Ribot's gradient, the older the memory is, the more likely that it has been consolidated and so it is harder to disrupt and be forgotten. So, which of them is correct? Well, they both are. The Ebbinghaus curve is correct because, over time, more and more information is forgotten. However, keep in mind that most of the action in the forgetting occurs early on, soon after learning. After that, the amount of forgetting tapers off considerably. Moreover, it is subject to Jost's Law, which captures the idea that the rate of forgetting actually slows down. The reason for this is that more and more memories have been well-consolidated, which is consistent with Ribot's gradient, making them less likely to be forgotten, and, thus, they are taken out of the pool of memories that can be forgotten. So, you can see that both Ebbinghaus's forgetting curve and Ribot's gradient contribute to the later likelihood that a memory will be available for retrieval.

STUDY IN DEPTH

Retrograde amnesia is fairly common. In any situation in which there is a possibility of head trauma, such as when concussions occur, there is a possibility for retrograde amnesia. Some of you may have had retrograde amnesia, if only in a limited form. A common cause of retrograde amnesia is contact sports, such as with American football.

A study of football players, concussions, and retrograde amnesia was done by Lynch and Yarnell (1973; Yarnell & Lynch, 1973). They lurked on the sidelines during University of Colorado football games. When players were injured, they were tested after they came off the field of play. Neurologically, the players were assessed briefly using funduscopy (using an ophthalmoscope to look into a person's eye), pupil reaction, and extraocular muscle function. These neurological exams revealed nothing remarkable.

For memory testing, six players were identified as having suffered "mild" concussions. Twelve additional players were tested as controls. Eight of these were tested when they came off the field following plays in which they were injured but not due to head trauma (e.g., torn ligaments). The remaining players were tested after coming off the field after a substitution but not following an injury.

All of these players were tested immediately (within 30 seconds) after coming off the field, as well as three to five minutes later. Memory was assessed at these times by asking the player to state his name, say what position he played and for which team, who his opponents were, and to describe the play that happened when he was injured.

All of the players, both the concussed and the controls, remembered the play that had just occurred when they were questioned within 30 seconds of coming off the field. However, three to five minutes later, or longer, players who had suffered a concussion could no longer remember the play that led to their injury. They had retrograde amnesia for those events.

This suggests that effects of retrograde amnesia may take time to establish themselves and be observed. Thus, the retrograde amnesia was not immediate. There was a delay of a minute or two between the time of the injury and the onset of the amnesia. It may be that the knowledge of the prior play was still in the players' short-term/working memory but that it could not be consolidated in the hippocampus as part of long-term memory as a result of the head trauma.

Much of what is lost in retrograde amnesia is autobiographical memories—memories that refer to events of one's own life—as well as personal semantic information, such as addresses and jobs, and public events, such as news stories. Again, the more recent the memories, the more likely they are to be lost. Nondeclarative memories are largely preserved, as well as semantic knowledge, although people may not be aware of acquiring this knowledge and may even deny having it.

PHOTO 18.1 *Retrograde amnesia can occur if there is a blow to the head, as would occur with a concussion in an automobile collision*

Source: kadmy/iStock/Thinkstock

When there has not been permanent brain damage, the recovery of memories follows a regular pattern, namely Ribot's gradient. Because older memories are more stable, they are the first to return. As time goes on, more memories are recovered. It is not unusual for many memories to be recovered at or close to their level prior to the incident. However, there is also a period of time just prior to the trauma for which memories are never recovered. This is because these memories have been permanently destroyed. The disruption hits them while they are in a very fragile state.

I have personal experience with retrograde amnesia. When I was 21, I worked as a bartender. One night, while driving home after work, I stopped at a red light on Franklin Avenue and was waiting to turn left onto my street, Belle Avenue. There was a car behind me and behind that car was a police cruiser. When the light turned green, I started to make the left turn and the cruiser broadsided my car, pushing the driver's side door into the middle of the car (it turned out that the police officer had just gotten a call and had sped off to answer it with no flashing lights or siren—as reported by the witness in the car behind me). I was taken by ambulance to the hospital half a block away. When I woke up in intensive care the next morning, I had no memory of the accident. And, even though it was July, I thought it was April. Over the next few days, my memories gradually returned but, even today, I have no memory of the day of the accident or the accident itself (thank goodness).

Case Studies of Retrograde Amnesia

Not all cases of retrograde amnesia follow the same pattern. What we have seen up to now is a typical pattern but it can appear in other ways. Stracciari et al. (1994) describe two young men who had closed head injuries resulting in a temporally limited retrograde amnesia. They had trouble remembering what had happened to them during the past year. This amnesia was limited to autobiographical memories but not semantic and public memories (such as current events). So, not all information was lost for the amnesic period. However, even important personal information was lost. For example, one of them forgot that he had been dating a particular woman for six months prior to the accident. This memory loss was profound enough that her name was unfamiliar to him—and he had her name tattooed on his forearm!

Although memories often return during recovery, in more severe cases they do not. One case without much improvement is that of P. S., who suffered profound anterograde amnesia as well (McCarthy & Hodges, 1995). As a result of a stroke when he was 67, P. S. sustained damage to his thalamus. The result was retrograde amnesia for all of his adult life, except for the period when he was in the British Royal Navy during World War II. Because of his added problem with anterograde amnesia, he believed himself to still be in this time. He interpreted and placed any knowledge within the framework of those war years. For example, while his autobiographical memory was severely compromised, he did have good memory for famous faces of the decades following World War II and he could place them in the correct temporal sequence. However, when asked to date this information he would place it in the early to mid-1940s. He did, however, have reasonably good memory for that time. When asked to describe his hometown, he could be very specific, but his description is of the town as it appeared in the 1940s. Here, the thalamus is not the storehouse of memories. Instead, it is a connection between different sources of information that would place memories in time and in P. S.'s life. When this connection was severed, P. S. became trapped in time.[2]

Electroconvulsive Therapy/Shock

Retrograde amnesia can also occur when a powerful electrical current is passed through the brain. In some cases this is done as part of a therapeutic treatment.

This is **electroconvulsive therapy**, or **ECT**. For ECT, electrodes are placed on the head. During ECT, the patient is strapped securely to a table and a series of electrical pulses is passed through the brain. Unless a person is administered anticonvulsant drugs, these shocks can make the whole body convulse violently and possibly be injured. Basically, the ECT treatment is inducing a grand mal seizure. This process is repeated six to 12 times over a three- to five-week period (Cahill & Frith, 1995). It is most often used with depressed patients after there has been little to no response to any other treatments and the patient is in a precarious state. ECT continues to be used and is effective at getting patients to a state where more conventional therapies can be used.

ECT has effects other than the alleviation of depressive symptoms, including amnesia. Initially, after ECT, there is a period of anterograde amnesia in which the person has trouble learning new things (Cahill & Frith, 1995). More prominent is the marked presence of retrograde amnesia (Cahill & Frith, 1995; Squire & Cohen, 1979), although some of the memories do eventually return. People undergoing this treatment lose memories from the recent past, including memories of the ECT session itself (which is probably a good thing). The amount of memory loss can vary but it can be as long as one or two years prior to ECT (Squire, Slater, & Chace, 1975) (see Figure 18.1). This memory loss is found for both personal autobiographical memories (a more episodic memory loss) and for community-shared public memories (a more semantic memory loss). However, implicit memory seems unaffected (Vakil et al., 2000).[3]

When used to study memory and not as a treatment, this procedure is called **electroconvulsive shock**, or **ECS**. It is used on laboratory animals, such as rats. ECS provides a systematic assessment of retrograde amnesia. When ECS is given to rats shortly after a fear experience, such as receiving a painful shock, retrograde amnesia occurs and there is no subsequent fear of that situation (Duncan, 1949; Madsen & McGaugh, 1961). In another ECS study by Chorover and Schiller (1965), rats were placed on a platform. If the rats stepped down from the platform, they received a shock, so they learned to no longer step down. Wires that delivered an ECS were attached to the rats' ears, and the amount of time between when rats stepped off the platform and the delivery of the ECS was varied. As can be seen in Figure 18.2, in a study by Duncan (1949), the shorter the delay between the shock and the ECS, the less likely that rats learned to avoid stepping down, because the ECS had disrupted their memories. However, if there was a lengthy period between stepping down and the ECS, this information was stored in the rats' brains and thus was more permanent, stable, and resistant to the disruption by the ECS.

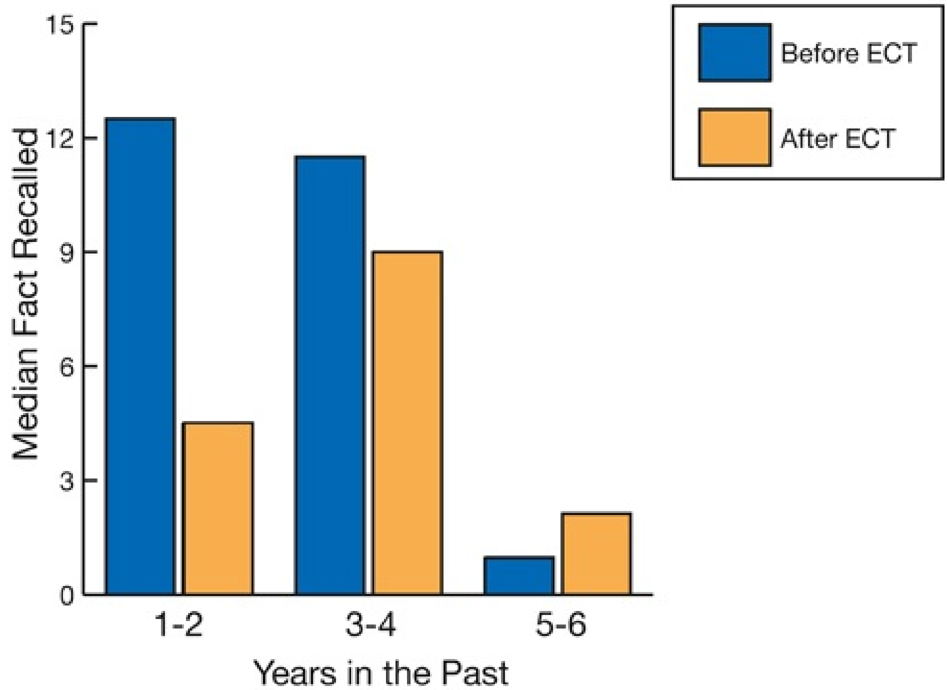

FIGURE 18.1 *Graded Effects of Retrograde Amnesia*

Adapted from: Squire, L. R., & Cohen, N. (1979). Memory and amnesia: Resistance to disruption develops for years after learning. *Behavioral and Neural Biology*, *25*, 115–125

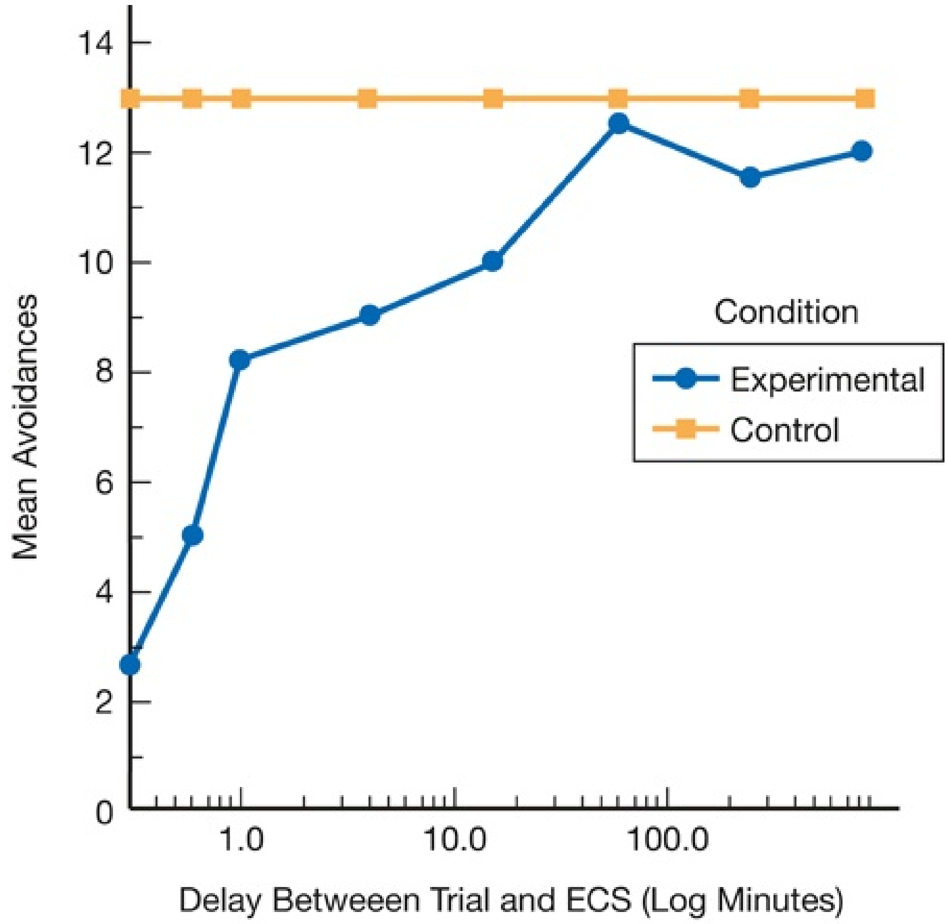

FIGURE 18.2 *Retrograde Amnesia Following Electroconvulsive Shock*

Adapted from: Duncan, C. P. (1949). The retroactive effect of electroshock on learning. *Journal of Comparative Physiological Psychology*, *42*, 32–44

Stop and Review

The loss of memories prior to an incident is retrograde amnesia, often involving a disruption of memory consolidation. This loss of memories follows Ribot's gradient, with newer memories being more susceptible to disruption than older memories. Over time, many of the memories initially lost are recovered, although those near the trauma may be gone forever. Retrograde amnesia can be induced using electrical shocks. When this is done therapeutically, it is known as electroconvulsive therapy, or ECT, whereas when it is done to study memory it is known as electroconvulsive shock, or ECS.

ANTEROGRADE AMNESIA

Whereas retrograde amnesia is the loss of memories prior to an incident, **anterograde amnesia** is the inability to store new memories after an incident. This is a much more devastating condition. With anterograde amnesia, people lose the ability to fully benefit from their experiences and they become, in some sense, frozen in time. Someone with severe anterograde amnesia needs to be given the same information repeatedly because they have great difficulty retaining it. Here, we first look at anterograde amnesia in terms of which part of the brain is damaged, namely either the medial temporal lobes and the hippocampus or the diencephalon. After this, we consider issues of anterograde amnesia more generally (see Aggleton, 2008, and Aggleton & Brown, 1999, for a suggestion that the same memory processes are disrupted in both cases).

H. M.: Medial Temporal Lobe and Hippocampus

The medial temporal lobes (BA 21) are adjacent to an important memory structure: the hippocampus. Damage to these areas of the brain as a result of surgical intervention, infection, stroke, or anoxia (lack of oxygen to the brain) can result in anterograde amnesia. Perhaps the most famous amnesic was Henry Molaison (February 26, 1926—December 2, 2008), better known as H. M. (Scoville & Milner, 1957). On August 23, 1953, at the age of 27, H. M. had brain surgery to relieve severe epilepsy. H. M. was having several petit mal seizures each day (up to 12 in a two-hour period) and weekly grand mal seizures, often resulting in injury. He was unable to work or lead a normal life. The surgeons removed much of his hippocampus and adjoining cortex on both sides. MRI scans (Corkin, Amaral, González, Johnson, & Hyman, 1997) showed that the brain damage included other structures, such as portions of the amygdala and temporal cortex. The parts of the hippocampus that did remain showed evidence of atrophy. In terms of his epilepsy, the operation was a success. The rate and severity of his seizures greatly diminished, although they were still present. Also, his intelligence stayed the same (if not improved) and his personality appeared unchanged. However, there was an unexpected side effect. H. M. had severe and dense anterograde amnesia. He was not able to learn new things.

Although H. M. had difficulty storing new memories, he had above normal intelligence. He had some retrograde amnesia for the time prior to the operation but most of his memories remained intact (Scoville & Milner, 1957). However, he had difficulty in daily life because he could not remember much beyond the span of his short-term memory. He often commented that he felt as if he had just awakened from a dream. It was not unusual for him to do a jigsaw puzzle many times or to read the same magazine over and over and not have any memory of having read it before. He enjoyed watching televised news but remembered nothing from it.

While H. M. had severe amnesia, not all of his memories were gone. He had a good short-term memory (Wickelgren, 1968) and his language abilities were largely intact (Skotko, Andrews, & Einstein, 2005). He could acquire new declarative memories with difficulty, if the information was salient enough and was repeatedly presented over a long period of time. For example, he was able to remember his father's death after he had been absent from home for about a month (Milner, Corkin, & Teuber, 1968). He also showed some evidence of implicit memory, such as perceptual identification (Milner et al., 1968), and procedural memory for motor tasks, such as mirror tracing or pursuit rotor tasks (Corkin, 1968). Note that H. M. was not the only person with severe anterograde amnesia. Other ways of acquiring this condition include loss of oxygen to the brain, brain tumors, neurological disorders such as epilepsy, or viral attacks such as herpes simplex encephalitis.

Diencephalic Anterograde Amnesia

The diencephalon is a collection of brain structures, including the thalamus, hypothalamus, and mammillary bodies. As with damage to the medial temporal lobes and hippocampus, damage to this area can cause anterograde amnesia. The most common way of acquiring this condition is as a symptom of **Korsakoff's syndrome**, which occurs in people who are chronic and severe alcoholics. They have damage in many brain areas, including the dorsomedial thalamic nuclei, the mammillary bodies, and the frontal lobe. This extensive brain damage is a function of a deficiency in thiamine (vitamin B1) as a result of alcoholism rather than an effect of the alcohol itself. It is also possible for the diencephalon to be damaged in other ways, such as through a stroke.

The diencephalon is associated with frontal lobe processing and the coordination and control of thought. People with anterograde amnesia from damage to these areas may confabulate (see Chapter 13). This kinds of anterograde amnesia may result in a decline in the ability to coordinate information in memory, making it difficult to recover it in an effective way. This decreased ability to coordinate information can also make it difficult to retrieve old memories.

Anterograde Amnesia More Generally

The part of memory most affected in anterograde amnesia is conscious, declarative memory, including episodic/autobiographical and semantic knowledge (but see Kitchner, Hodges, & McCarthy 1998). If you were to have a conversation with an anterograde amnesic, he or she might seem more or less normal, maybe a little off. If you were to get up, leave, and return 10 minutes later, he or she would not recognize you and may claim to have never met you before.

Anterograde amnesics do not show distinctiveness and novelty effects, such as the von Restorff effect (Kishiyama, Yonelinas, & Lazzara, 2004). Due to deficits in long-term memory encoding, they do not have the pool of memories needed to keep track of context. Because distinctiveness is defined by the context in which information is found (e.g., elephant is distinctive in a list of vehicles but not in a list of zoo animals), no von Restorff effect is seen. Relatedly, because these people have less awareness of past encounters, they are less likely to use definite articles when referring to objects (e.g., “the chair”) and are more likely to use indefinite articles (e.g., “a chair”) (Duff, Gupta, Hengst, Tranel, & Cohen, 2011). With standard language use, definite articles often refer to things that have been mentioned or encountered before. A shift in language use could reflect changes in the availability of information in memory.

As noted in Chapter 7, episodic memory processing involves not only memory for past events but also the ability to imagine future events. This is all part of the ability to engage in mental time travel. Consistent with the idea that mental time travel into the past and the future involves similar neurological processes, people with anterograde amnesia not only have trouble remembering events from the past; they also have trouble imagining the future (Hassabis, Kumaran, Vann, & Maguire, 2007; Rasmussen & Berntsen, 2014). Thus, anterograde amnesia truly does trap people in time.

Not all memory functions are seriously affected with anterograde amnesia. For example, short-term memory is largely intact (Baddeley & Warrington, 1970) but people forget things much faster (Warrington & Weiskrantz, 1968). So, amnesics comprehend the events as they happen but these experiences slip away quickly. Note also that, as with H.M., nondeclarative memory is relatively intact. Anterograde amnesics can learn new procedural tasks, although they may lack conscious awareness of doing so (Brooks & Baddeley, 1976). An example of an anterograde amnesic learning on a mirror tracing task is shown in Figure 18.3

Another well-known case of anterograde amnesia is Clive Wearing, a famed British classical musician who suffered from herpes simplex encephalitis in 1985 (Wilson, Baddeley, & Kapur 1995). Despite his profound anterograde amnesia, his musical abilities remained largely intact, allowing him to play or conduct as he had done before, with degradations noticed only by expert musicians (Wilson & Wearing, 1995).

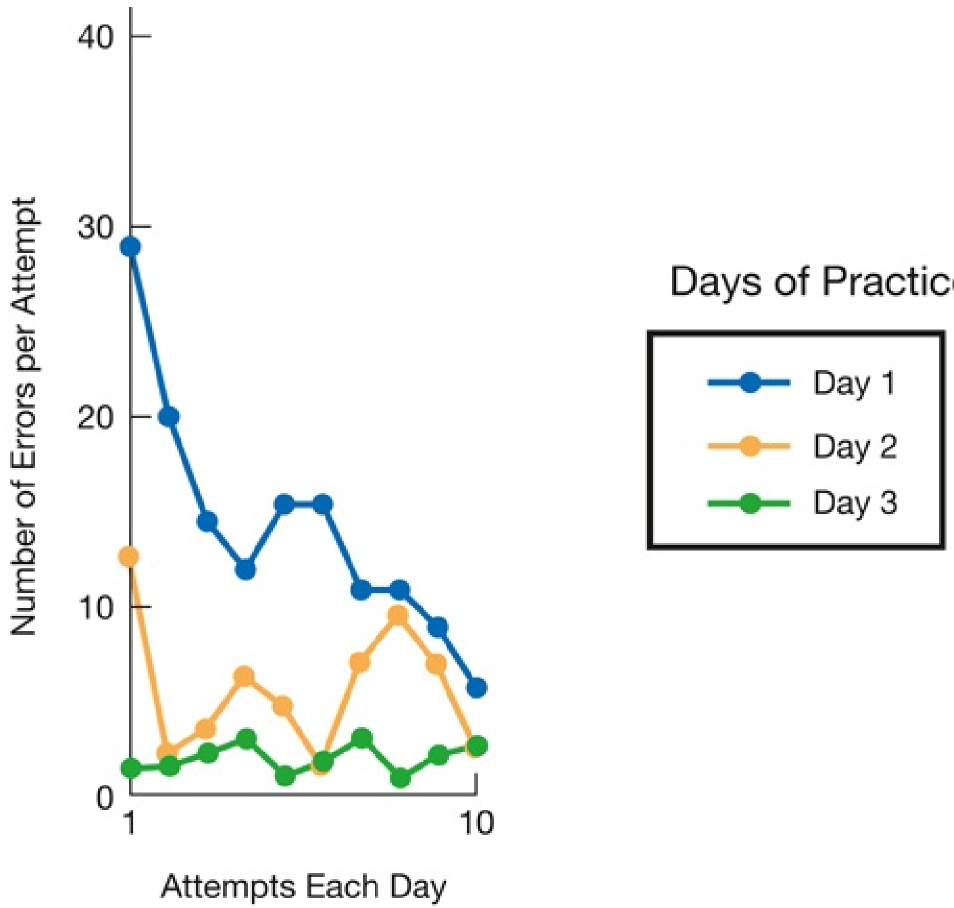

FIGURE 18.3 *Performance of an Anterograde Amnesic on a Mirror Tracing Task, Illustrating Preserved Implicit Memory*

Adapted from: Blakemore, C. (1977). *Mechanics of the Mind*. Cambridge: Cambridge University Press

The preservation of nondeclarative memories also applies to implicit, linguistic tasks (Schacter, 1987), such as the syntactic, semantic, and episodic priming of words (Ferreira, Bock, Wilson, & Cohen, 2008; Graf & Schacter, 1985; Graf, Shimamura, & Squire, 1985), although such priming is more likely to be preserved when it depends on perceptual, rather than semantic, characteristics (Rajaram & Coslett, 2000). Amnesics also perform similar to nonamnesic people on word fragment, word-stem, and perceptual identification tasks (Graf, Squire, & Mandler, 1984; Warrington & Weiskrantz, 1970). For example, amnesics spend less time viewing pictures that are repeated. However, if something in a picture has been altered (e.g., the relationship among elements is changed), nonamnesic people spend more time looking in the region where the change occurred, whereas amnesics do not (Ryan, Althoff, Whitlow, & Cohen, 2000).

Again, it is important to keep in mind that no memory test is process pure. There is always an influence of multiple memory components. The combined influence of explicit and implicit memory on a direct memory task can be seen in amnesics with recall and recognition. In Chapter 10, we saw how recall requires effort to generate information, whereas recognition requires only that people, at a minimum, believe that the information is old. A feeling of familiarity does not require conscious recollection but only unconscious, implicit influences. As such, anterograde amnesics have more difficulty with recall than with recognition. In some cases they may even show no recognition deficit in conjunction with a clear recall deficit (Hirst et al., 1986; Hirst, Johnson, Phelps, & Volpe, 1988).

Other Case Studies of Anterograde Amnesia

Is it possible for people to have anterograde amnesia for some types of information but not others? One case is that of A. B., who, as a result of a hematoma, had damage to his left posterolateral frontal lobe (BA 4) and adjacent anterior parietal lobe (BA 1, 2, and 3). A. B. could not retain word or sentence lists in short-term memory. However, he could recall complex stories he read or heard. Thus, A. B. had anterograde amnesia for words and unrelated sentences but had more normal memory for complex, interrelated, and meaningful prose (Romani & Martin, 1999). In other words, A. B. had poor memory at the surface form and textbase levels but good memory at the mental model level (see Chapter 7).

Another amnesic with selective problems is T. R. (Sirigu & Grafman, 1996). He suffered cerebral anoxia after heart failure and then had amnesia consistent with damage to the hippocampus. Like many anterograde amnesics, T. R. had difficulty with new episodic memories. However, for him, it was only for certain types of information. He remembered events but only in terms of what happened and where they happened. However, he was amnesic for the identities of the people involved and for when the events happened. This shows a selective loss for some episodic information, but not for others.

Living with Anterograde Amnesia

As you can imagine, anterograde amnesia has a profound effect on the ability to function normally. For example, people with anterograde amnesia may leave kitchen appliances on, fires burning, water running, and so on. They have a tendency to overeat because they consume multiple meals, not remembering that they had just eaten (Higgs, Williamson, Rothstein & Humphreys, 2008). Is there anything that can be done to help these people? Well, it depends on how severe the amnesia is. Some people may have relatively mild amnesia, which allows for some independence, whereas others are profoundly affected. Some amnesics are described here for whom treatment has been attempted.

One of these was a special education teacher, Sheila Moakes (Kapur & Moakes, 1995). She became amnesic when a case of herpes simplex encephalitis, at the age of 32, damaged parts of her temporal lobe and hippocampus, leaving her with some retrograde amnesia and profound anterograde amnesia. Although she can no longer work as a regular teacher, tracking students across the school year, she is able to tutor students on a lesson-by-lesson basis. She can also do many household tasks, though only by keeping to a strict schedule (otherwise she does not do some things and does others repeatedly), and she can do light grocery shopping if she has a list and does not have to go to a new store. She can still drive well, with her only problem being that she may become lost if she ventures too far from home. She does watch television but avoids shows that have a plot that must be remembered. She also does not read much for the same reason. Some parts of her life have continued to deteriorate. She has become distant to her son and has lost many of her old friends and has not been able to make new ones. She has also lost the motivation to learn new tasks because she knows the enormous effort that is involved.

If amnesia is milder, people become aware of the problem and develop strategies to compensate for the loss, such as the case of J. C. (Wilson, J. C., & Hughes, 1997), a former law student, who became amnesic after an attack of herpes simplex encephalitis. Because of some spared memory and his high intelligence and motivation, he was able to overcome this disability to some degree. Although he had to quit law school, he was able to train to become a professional furniture refinisher. Still, it took him 20 trips to learn where to get off the bus for refinishing school. He also went on to start his own business. To keep his life in order, he developed a system using a watch with multiple alarms and a color-coded system for keeping notes about events in his life. If he goes to a new restaurant with friends, he needs to write down that he went and what he ate, because he won’t remember. J. C. also started a new romantic relationship, but he must record facts about his activities with the woman. He also needs to leave himself constant reminders, such as “clean contact lenses” or “check the oven.” His life critically depends on sticky notes.

J. C. was able to show remarkable adaptation due in large part to the tremendous amount of support he gets from his family and friends. However, not all anterograde amnesics are so fortunate. For example, Mr. S. became amnesic in his 70s as the result of a stroke (Squires, Hunkin, & Parkin, 1997). Although he used a notebook for reminders in the beginning, a lack of reinforcement from his wife and friends, as well as his own lack of motivation, made him soon stop. There was no improvement for Mr. S.

Mixture of Retrograde and Anterograde Amnesia

As noted earlier, it is rare to have only retrograde or anterograde amnesia. Here is a case of severe trauma in which both were present and how they changed over time (as reported in Barbizet, 1970). An overview of the situation is given in Figure 18.4. Initial testing occurred five months after the trauma, in which there was both retrograde and anterograde amnesia. For the retrograde amnesia, the person was unable to remember events from the two years prior to the accident and had only partial memories for the time before that. For the anterograde amnesia, the person was not able to remember much of what happened after coming out of the coma and had trouble storing new memories.

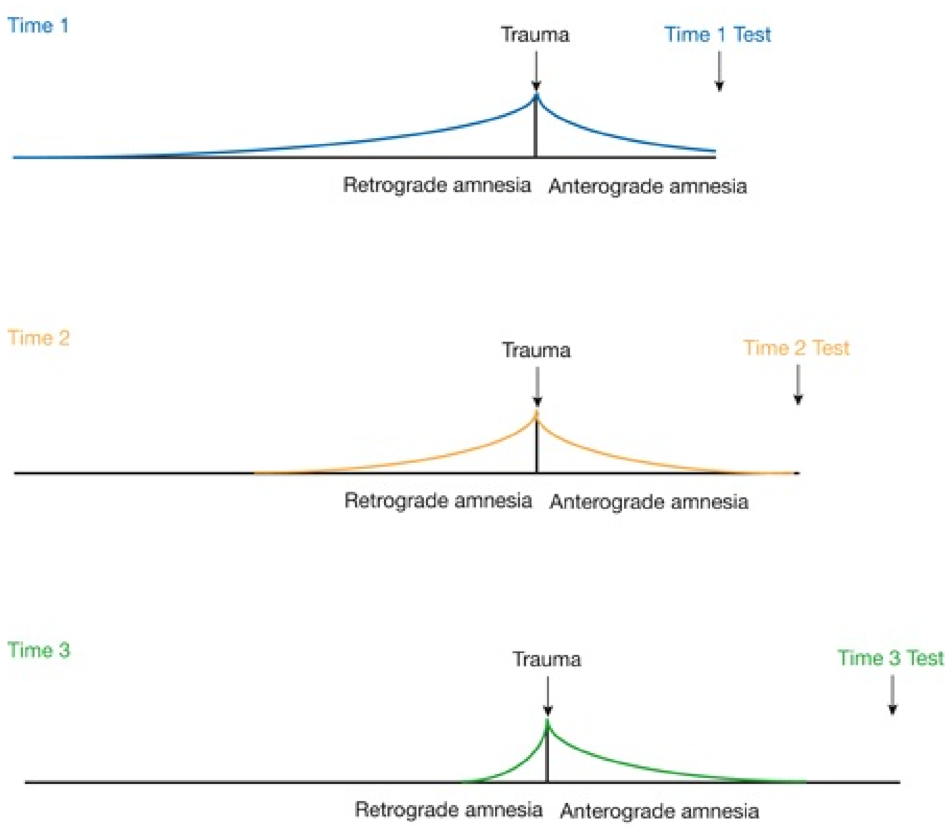

FIGURE 18.4 *Illustration of Brain Damage Resulting in Both Retrograde and Anterograde Amnesias*

Adapted from: Barbizet, J. (1970). *Human Memory and Its Pathology*. San Francisco, CA: Freeman

As time progressed, things improved. The retrograde amnesia severity eased. By eight months after the trauma, there was dense amnesia for only one year, with partial amnesia for four years prior to that, and most other memories had returned to a normal. Ten months later, most of the retrograde amnesia had lifted, leaving only dense amnesia for the two weeks prior to the trauma, never to be recovered. As for the anterograde amnesia, there was some improvement as well. By eight months after the trauma, some new information was being stored in long-term memory, and by 18 months memory had returned to a normal level. It is only for the three and a half-month period after the person emerged from the coma that there are no memories. Presumably, during this time the person was not able to store information effectively so it will never be remembered.

Stop and Review

The loss of the ability to store new memories after to a trauma is anterograde amnesia. This is caused by damage to either the medial temporal lobes and hippocampus or the diencephalon. An example of the first type is the case of H.M., who had his hippocampus surgically removed. Examples of the second are Korsakoff’s syndrome patients. People with anterograde amnesia have difficulty learning new information beyond what is held in short-term memory. Most of this memory loss is for declarative information. They also have trouble imagining future events. Other types of memory are more preserved, such as short-term and nondeclarative memory. People with anterograde amnesia find it difficult to carry on with their lives, although some limited success is possible. It is important to note that, while retrograde and anterograde are treated separately here, it is rare to find cases of one without some degree of the other.

Transient Global Amnesia

The types of amnesia that we have been talking about are the consequence of a clear traumatic injury, with no ambiguity about what brought it about, and the amnesia lasts for a substantial period of time. However, there is a form of amnesia that can occur where the cause is organic but the duration is very brief. This is **transient global amnesia**, or **TGA**. The amnesia is transient because it only last for a short period of time and does not endure. The amnesia is global, with both retrograde and anterograde components covering almost all memories from a given period of time. Thus, this is an unusual and hard to study memory disorder.

TGA episodes are short-lived, lasting only a few (typically three to eight) hours. A distribution of TGA durations is shown in Figure 18.5. Thus, TGA is not a permanent change but a temporary memory state. That said, there is some evidence that some deficits may linger for several days (Kessler, Markowitsch, Rudolf, & Heiss, 2001). The fleeting nature of TGA makes it hard to study. Although the concept of TGA has been around since Ribot (1882), and was originally labeled by Fisher and Adams (1964), it has been difficult to study until recently. Often, by the time a knowledgeable person is notified, the amnesia has begun to clear. Additionally, many incidents surely go unreported. For example, if people have the beginning of a TGA in the evening, they might go to bed and, by morning, most of the symptoms have begun to clear.

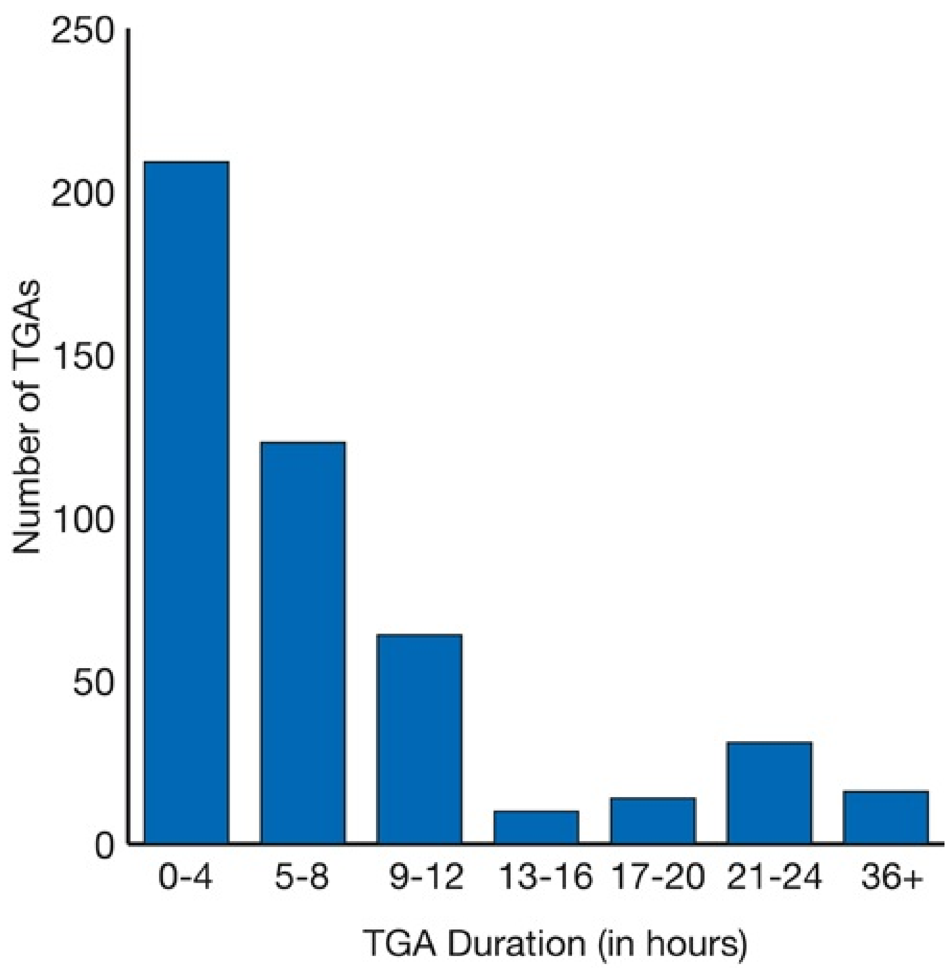

FIGURE 18.5 *Duration of a Transient Global Amnesia*

Adapted from: Brown, A. S. (1998). Transient global amnesia. *Psychonomic Bulletin & Review, 5*, 401–427

During a TGA attack, a person has no memories of the recent past, anywhere from a few hours to several decades, although in most cases the memory loss is for a few months. This range of memory loss is shown in Figure 18.6. As can be seen, the amnesia does not cover all of one's life but, again following Ribot's gradient, only the weaker, less consolidation memories are prone to disruption. This amnesia can be very dense in terms of the memories that are lost. For example, one man was surprised to see that some fingers on his left hand were missing, having been lost in a farm machinery accident four months before. This suggests that even very traumatic and emotional memories can be disrupted during a TGA.

Often during a TGA episode, people are confused and repeatedly ask the same questions. This is because of an anterograde amnesia component that prevents them from remembering that they had already asked the question and gotten an answer. Although working memory appears fine, episodic knowledge is not retained or recovered. Semantic and procedural knowledge seems unaffected. Although some affected people are aware of the memory problems they are having, many have only a general awareness that something is not right, and some may even be unaware of any memory problems. They simply know that something is off. People often exhibit signs of anxiety and depression while in the TGA state (Hainselin et al., 2012).

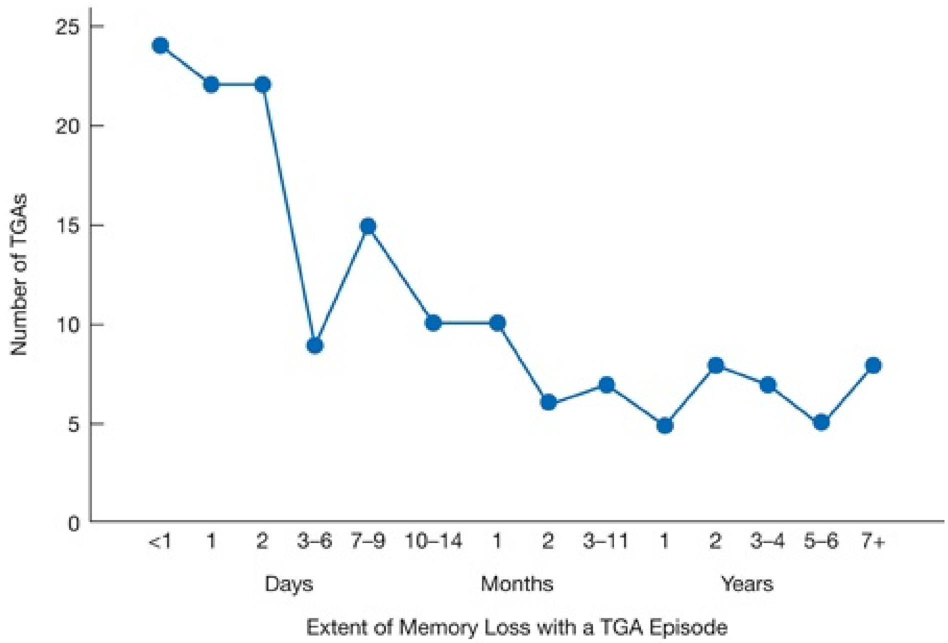

FIGURE 18.6 *Degree of Retrograde Amnesia During a Transient Global Amnesia Episode*

Adapted from: Brown, A. S. (1998). Transient global amnesia. *Psychonomic Bulletin & Review*, *5*, 401–427

Part of what makes TGA so mysterious is that there is no clear indicator of its cause. A person seems fine but then is suddenly experiencing a dense memory loss. As illustrated in Figure 18.7, TGAs often occur in people between the ages of 50 and 70, and typically only occur once in a lifetime. It has been suggested that TGAs are brought about by an emotional or physical stress or exertion, such as having an argument, playing an exciting card game, having sex (the most popular way to get it), driving, taking a hot shower, or having a coughing spell.

TGAs may be a result of ischemias (temporary disruptions of blood flow) in the brain. The parts of the brain that are most often implicated are the temporal lobes, hippocampus, and thalamus (Brown, 1998; Goldenberg, 1995). There is even some evidence that area CA1 of the hippocampus may be affected (Bartsch & Deuschl, 2010).

Stop and Review

The temporary and extensive loss of memories is transient global amnesia, or TGA. The duration of a TGA episodic is typically short, often lasting less than 24 hours. Despite the limited duration, the amount of memory loss can be extensive and follows Ribot's gradient. People are often in a confused, anxious, and depressed state during a TGA and may not be fully aware of their memory problems. TGAs follow periods of stress or excitement and involve a disruption of blood flow.

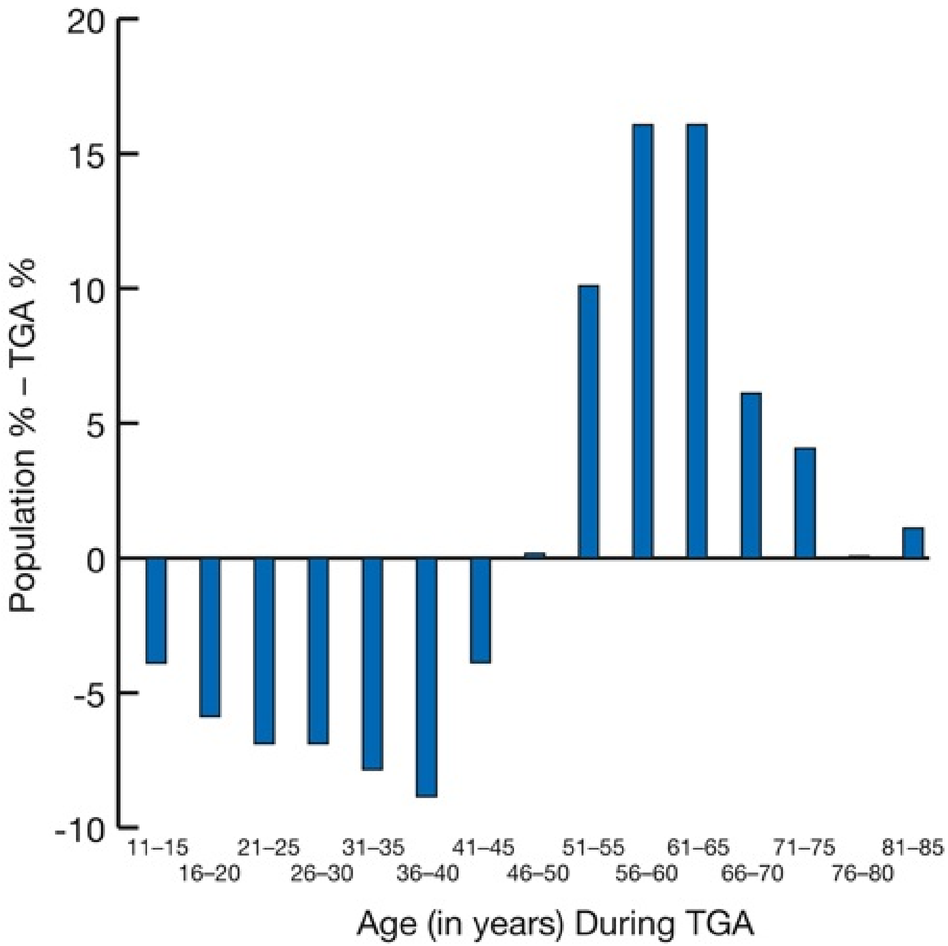

FIGURE 18.7 *Age at Which a Transient Global Amnesia Episode Is Experienced*

Adapted from: Brown, A. S. (1998). Transient global amnesia. *Psychonomic Bulletin & Review*, *5*, 401–427

LOSS OF MEMORY OF SPECIFIC KNOWLEDGE OR SKILLS

The distinction between autobiographical and semantic memories is observed with certain types of amnesia. For example, it is possible for people to have trouble with semantic memory but not autobiographical memory. Yasuda, Watanabe, and Ono (1997) describe a patient, M. N., who sustained damage from a tumor to her right hemisphere, where the frontal and temporal lobes meet. She was able to give accurate accounts of her autobiographical memories, such as where she had gone to school, the places she had worked, and the various illnesses she had. However, she had difficulty identifying and remembering public events, recalling only 20% of those that most people could recall at a 100% level. She had problems with historical figures and famous monuments. This problem with semantic memory leads us to a condition called semantic amnesia.

Semantic Amnesia

Semantic amnesia is a deficit in the ability to retrieve semantic knowledge, often as a result of damage to the temporal lobes, particularly in the anterolateral portions (BA 38) and more likely with damage to the left hemisphere (Hodges, Patterson, Oxbuy, & Funnell, 1992; Snowden, Goulding, & Neary, 1989). This is a rare condition in the absence of other neurological syndromes, such as Alzheimer's disease. This is because so many sources of damage tend to also affect other areas. Moreover, this part of the brain is well supported; for example, this part of the temporal lobe is maintained by two major arteries. This makes it less likely to be damaged by a stroke.

People with semantic amnesia have difficulty retrieving word meanings, even for common words, despite otherwise normal language. For example, a person with semantic amnesia may not be able to remember what a cat or a robin is or whether a mouse has a beak or a long, skinny tail (Funnell, 1995). This loss is called **anomia** and can be very specific. For example, patient G. R. had difficulty with famous names but not with the names of friends or historical or literary figures (Lucchelli, Muggia, & Spinnler, 1997). G. R.'s memory for facts about a person was intact, such as knowing their line of work and any distinguishing achievements or physical features. The trouble was in remembering the names of celebrities. For a first-hand account of the experience of anomia, see Ashcraft (1993).

With semantic amnesia and anomia, other parts of memory, including non-declarative and episodic memories, are relatively intact. What distinguishes it from aphasia is that people also have difficulty with semantic judgments that do not require language, suggesting that semantic memory has been damaged

(Bozeat et al., 2000). People have difficulty not only with the names of objects but also how objects are used. This is called **apraxia**. They may try to use objects incorrectly, such as trying to use a match as a pencil. Because of this, such people need to be monitored to avoid harming themselves. It should be noted that they may be able to use some objects appropriately in cases where the use of the object is clear and constrained (Hodges et al., 2000)—for example, using a pair of scissors with a piece of paper. There are only a limited number of ways that the scissors lend themselves to being used and many people with apraxia perform normally.

Semantic amnesia can be restricted to particular types of information. This is illustrated by patient A. B. R., whose semantic amnesia occurred after a period of anoxia during open heart surgery. A. B. R. had trouble identifying pictures (but not names) of famous people (e.g., Queen Elizabeth and Napoleon) and landmarks (e.g., the White House and the Parthenon). The rest of his memories were relatively intact (Kartsounis & Shallice, 1996). Another distinction that may be affected is between abstract and concrete ideas. In normal people, concrete ideas (such as sock, pencil, dog, etc.) are easier to remember than abstract ones (such as truth, love, redemption). However, another patient, D. M., could identify abstract but not concrete words (Breedin, Saffran, & Coslett, 1994). A similar isolation in semantic amnesia can occur for knowledge of natural kinds versus artifacts.

Thus, there are a variety of ways that memory can be affected in semantic amnesia. In an effort to bring some clarity to understanding semantic amnesia, Cree and McRae (2003) broke down the trends seen in the various deficits into dimensions of processing. Essentially, these dimensions capture salient characteristics of knowledge, each of which is handled by a different part of the brain. Each dimension separates out different types of knowledge. These dimensions are listed below.

Dimension 1. Visual motion/complexity versus frequency/function
Dimension 2. Distinctive sounds versus distinctive features or names
Dimension 3. Touch/taste/color versus parts/textures
Dimension 4. Smell/correlated features/encyclopedic features versus parts/textures

(Cree and McRae, 2003, p. 190)

The breakdown of semantic knowledge helps us understand the complexity of semantic information in normal people, and future theories of semantic memory need to take these findings into account. Moreover, it also helps us understand the problems that people face with semantic amnesia. Once we better understand their deficits, we can then link them with underlying neurological or psychological problems and be better prepared to treat them.

Before leaving semantic amnesia, let's think about what is going on in episodic memory a little more. As a reminder, with semantic amnesia, despite problems in semantic memory, even complex forms of episodic memory, such as autobiographical memory, appear to be preserved (Simons, Graham, & Hodges, 2002). These autobiographical memories can be used to guide semantic dementia patients to derive semantic-like knowledge. Memories of previous experiences can help people derive some semantic understanding, even though semantic memory itself may be compromised (Graham, Ralph, & Hodges, 1997). For example, one person could remember the names of people she played golf with frequently by using autobiographical memories but she would not be able to remember the names of people she had played with in the distant past or the names of famous golfers. Although there is some preservation of episodic memory, it is incomplete. There is an odd reversal of Ribot's gradient with semantic amnesia, particularly for semantic aspects of those events, such as people's names (Piolino et al., 2003).

Aphasia, Amusia, and Prospagnosia

Semantic amnesias that are exclusive to certain types of knowledge are treated as separate conditions. In some cases, people may lose the ability to use language. This is called **aphasia**. Because language is usually located in the left hemisphere of the brain, this is typically a result of damage to that area. There are two general kinds of aphasia. One is **Broca's aphasia**, which occurs when there is damage to caudal portions of the frontal lobe and adjoining portions of the temporal lobe (BAs 44 and 45). This is near the motor cortex of the frontal lobe. In this condition, a person has difficulty producing language but language comprehension is better preserved. Another aphasia is **Wernicke's aphasia**, which occurs with damage to the posterior temporal lobe and the adjoining portions of the parietal lobe (BA 22). Here, people have difficulty comprehending language but language production is better preserved. This decline can get to the point where people cannot even monitor their own language. As a result, they produce a word salad that is grammatically correct but semantically anomalous. A condition that is related to aphasia is **amusia**. People with this deficit may have trouble either comprehending or producing music.

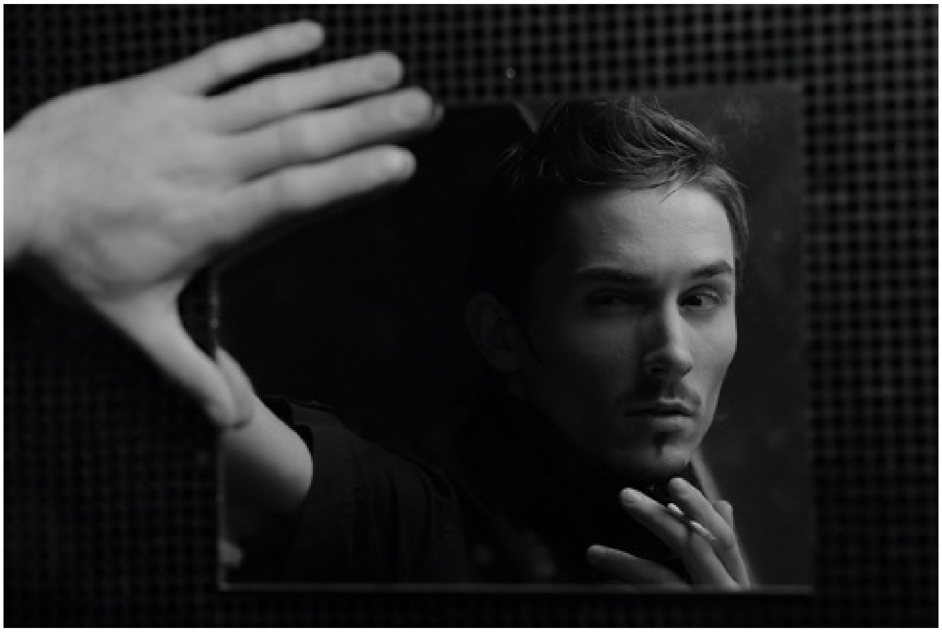

PHOTO 18.2 *Some types of amnesia target only specific memory functions: people with prosopagnosia have trouble recognizing faces (they may not even recognize their own faces in a mirror)*

Source: Artsiom Kireyau/Hemera/Thinkstock

Another specific memory loss is **prosopagnosia**, or a failure to recognize faces, which can occur after damage to the fusiform gyrus (BA 37). People with this condition retain memories of different people but are unable to recognize a person's face, even when they know that person well. Patients may not even be able to recognize their own faces in a mirror. These patients must use other cues to identify someone, such as a person's voice. Thus, different types of knowledge about people use different parts of the brain. Memory retrieval is not a discrete process of remembering. Instead, people may be able to partially remember some information but not all of it.

Short-Term Memory Amnesia

Most amnesias affect long-term memory, with preserved short-term memory function. However, there are cases where short-term memory is damaged and long-term memory is less affected (Belleville, Caza, & Peretz, 2003). One example is the case of K. F., who had a serial position curve recency effect of only one item (normal people have recency effects of five or six) (Shallice & Warrington, 1970). However, long-term memory was relatively intact. Also, there is the case of P. V. (Vallar & Baddeley, 1984; Vallar & Papagano, 1995), who had difficulty remembering spoken words over the short term but had normal memory for visually presented lists and good long-term retention. This led P.V. to have problems "understanding" short sequences that required short-term memory, such as phone numbers or the prices of goods. She also had trouble doing mental calculations.

Many verbal short-term memory amnesias involved damage to the left parietal lobe (Vallar & Papagano, 1995)—in particular, the supramarginal gyrus (BA 40). In some cases, premotor areas of the frontal lobe are also implicated (e.g., Broca's area). This disrupts short-term memory rehearsal and can have a spillover effect to influence more complex thinking, such as sentence comprehension. For example, people with verbal short-term memory amnesia would have difficulty understanding sentences like "touch the small green square and the large black circle" or "the cat that the dog chased was white." Comprehending these sentences requires keeping track of the words and the order in which they were heard. People are less able to guess the intended message if some words, or their order, are forgotten. People with short-term memory amnesia must use other sources of information. For example, patient I. R. could not use phonological information to help her remember, but could use semantic information from long-term memory (Belleville et al., 2003).

Not all short-term memory amnesias are verbal processing deficits. Some, following damage to the right parietal/occipital lobe, result in visuospatial memory problems (Vallar & Papagano, 1995), such as having difficulty counting the number of dots on a computer screen, identifying unfamiliar faces, doing mental rotation, or learning the way around an unfamiliar house.

Stop and Review

It is possible to have selective deficits that target memory for some types of information but leave others relatively intact. With semantic amnesia, people have difficulty retrieving semantic information about the world, which makes it difficult to understand what is going on. However, episodic and autobiographical memories are more preserved. Memory loss can also target specific abilities, such as loss of language skill with aphasia, loss of music skills with amusia, loss of object name knowledge with anomia, and loss of the ability to recognize faces with prosopagnosia. Whereas most amnesias strike long-term memory, it is also possible to have primarily short-term memory damaged.

PSYCHOGENIC AMNESIA

The amnesias we have seen so far are the result of clear physical brain damage. There are other types of amnesia that may arise based on psychological content. That is, a person may be so psychologically disturbed by something that it causes them to forget on a massive scale. These are **psychogenic amnesias** because they are brought about by psychological rather than neurological mechanisms, although in some cases there may be neurological damage that is not detected, making the amnesia only appear to be psychogenic (Kopelman, Green, Green, Lewis, & Stanhope, 1994; Markowitsch, 2003). In most cases, the memory loss is associated with a traumatic event or circumstances in a person's life, such as the loss of a beloved parent, and the knowledge lost is usually episodic or autobiographical in nature. Semantic and procedural memories remain intact. The memory loss may be a way of coping with the trauma. If the oppressive knowledge is not consciously remembered, then it will no longer be stressful and anxiety provoking.

A concern with reports of psychogenic amnesia is that some or all of these people may be malingering and faking their conditions. In fact, with careful memory tests, some patients have been found to be simulating at least some of their symptoms (Kopelman, Christensen, Puffett, & Stanhope, 1994). This may be done because a person is trying to avoid prosecution or some other negative outcome. That said, there is also some evidence that people who do not claim to remember their crimes may actually be amnesic for those periods of time (Pyszora, Barker, & Kopelman, 2003). With this in mind, let us look at some of the ideas for what psychogenic amnesia might be and how it might manifest itself in terms of impaired memory performance.

Repression

One of the best-known forms of psychogenic amnesia is **repression**, a concept associated with Freud and his followers. This view suggests that there are experiences people have that are traumatic or threatening to the point of potentially damaging the ability to function adequately in the world. These can be any number of traumas, including sexual abuse, violence, or even inappropriate sexual desires or feelings. To protect people from these damaging memories, a part of the mind actively represses them to keep them from entering consciousness. As such, repression is a defense mechanism.

The experimental support for repression is scarce. By its very nature, repression is difficult to study. First, one must recover repressed memories, but a problem is not knowing how accurate such memories are. As we saw in Chapter 13, it is easy for false memories to be generated and there is no clear way, apart from independent evidence, to distinguish real recovered memories from false ones (Loftus, 1993). One of the more intense debates in memory research has been whether recovered repressed memories are real. Some people have argued that there is no such thing as repression. All recovered repressed memories are either false memories or not really repressed in the first place. There are two lines of argument for this view. One is that many of the methods used to recover repressed memories are similar to those that would be used to generate false memories. Another point is that the typical outcome for highly traumatic experiences is that people remember them very vividly and have difficulty forgetting them, even when they want to do so, as with people who have PTSD. This is the opposite of repression.

Dissociative Amnesia

Another psychogenic amnesia is **dissociative amnesia**, in which people are unable to remember segments of their lives (Kihlstrom & Schacter, 1995). Typically, the forgotten knowledge is either traumatic in itself or is associated with a traumatic event. For example, suppose you were the driver of a car in an accident that resulted in someone's death. If this pathologically troubled you, you might acquire dissociative amnesia by which you do not remember any of the events of that day. What makes this condition distinct from repression is that a person is aware of the memory loss and is troubled by it, whereas this is not the case with repression.

There are three ways for dissociative amnesia to manifest itself (Nemiah, 1979). The first is as a **systematized amnesia**, where people are amnesic for information related to a traumatic event, regardless of when or where it occurred. Second is **localized amnesia**, in which a person has trouble remembering events within a block of time, such as a period of hours or weeks. Finally, with **generalized amnesia**, nearly all of a person's life is forgotten. These different ways that dissociative amnesia manifests itself illustrate the psychological influence of its origins. This selectivity or breadth of coverage is almost never seen with organic amnesia.

Dissociative Fugue

A more profound psychogenic amnesia is a **dissociative fugue**, in which memory is disrupted to the point that people forget fundamental aspects of their identity, such as who they are, where they live, and what they do for a living

(Kihlstrom & Schacter, 1995). There are different fugue states depending on the nature and extent of the loss (Fisher, 1945; Fisher & Joseph, 1949). First, there may be a change in both identity and location (where the person lives)—this is **fugue and flight**. Second, there may be a loss of memories, but the core identity is intact—this is **memory fugue**. Finally, there may be a reversion to an earlier state of life, with an inability to remember events after that period—this is **regression fugue**. Again, this sort of memory loss is psychological and is not seen with organic damage.

Although conscious awareness of previous memories is rendered inaccessible in the fugue state, if this were like other amnesias one would expect implicit memory to be unaffected. This has been difficult to test, especially because the fugue state is so rare. However, there is some anecdotal evidence consistent with this idea. A dramatic illustration of preserved implicit memory of a fugal amnesic is a case of a woman who had been found wandering around but could provide no information about herself. She was asked to dial a random number on a telephone. This number turned out to be her mother's (Lyon, 1985).

What is more fascinating is that when a person comes out of the fugue state, even if it had been going on for years, not only do memories from the original identity return but memories from the fugue identity become forgotten. This return to the original identity can be slow or fast. Thus, even when there has been a recovery of the original identity, there is still an amnesia associated with this condition.

Dissociative Identity Disorder

A final psychogenic amnesia is involved in **dissociative identity disorder**,[4] in which people act as if they have many separate identities, each with its own autobiographical history. In some cases these alternative identities are aware of the others. Often it is found that one identity has no conscious memories of what another identity learned while he or she was dominant. In dissociative identity disorder, there may be asymmetrical amnesia across identities (Kihlstrom & Schacter, 1995). That is, one identity may be able to remember information that was learned when a second identity was dominant but not vice versa. This bears some resemblance to dissociative fugue, where the shift from one identity to another results in some amnesic forgetting of information learned while involved with a previous identity.

Still, this amnesia does not apply to all memories. Like organic amnesia, implicit memories may be intact with an otherwise amnesic loss across identities, as with procedural memory learning (Kihlstrom & Schacter, 1995) or priming (Huntjens et al., 2002). These implicit priming effects appear to spread across identities more for tasks that influence perceptual processing, such as picture fragment completion, than for tasks that rely more on conceptual knowledge, such as word-stem completion, which can show amnesia across identities (Eich, Macaulay, Loewenstein, & Dihle, 1997).

Stop and Review

It may be possible for people to be amnesic from psychological trauma. These psychogenic amnesias include repression, dissociative amnesia, dissociative fugue, and dissociative identity disorder. Repression involves the mind keeping psychologically threatening information from entering consciousness. The evidence for his condition is weak. Dissociative amnesia is similar to repression, except that people are aware of their memory loss and are bothered by it. Dissociative fugue is a state in which people lose autobiographical memories for an entire prior identity. This prior identity may return but will then have complete amnesia for the replacement experiences. Finally, dissociative identity disorder involves a person having multiple identities, with a frequent symptom being amnesia from one identity to another. This amnesia is often asymmetrical and is confined to more conceptually driven processes and less, if at all, to more data-driven processes.

PUTTING IT ALL TOGETHER

Amnesia is the catastrophic loss of memories—a pathological forgetting. The various types of amnesia reinforce the idea that memory is not one thing. It is a made up of different parts and components that typically work together is a harmonious way. Amnesia can be oriented toward the past or the future, as with the distinction between retrograde and anterograde amnesia, each being brought about by different types of brain damage. Amnesia can be short in duration, as with some retro grade amnesias and transient global amnesia, or permanently altering people's lives, as with anterograde amnesia. Amnesia can come about from organic or psychologic trauma. The suggested psychogenic amnesias are repression, dissociative amnesia, fugue states, and the memory loss that accompanies dissociative identity disorder.

Much of what we know about memory and the principles that it operates under come from studies of people struck with amnesia. The loss of memories can follow Ribot's gradient, highlighting the fact that your memories go through a gradual process of consolidation. The distinction between short- and long-term memories is reinforced by the finding that people can have either short- or long-term memory amnesias. Moreover, short-term memory amnesia may target either verbal or visuospatial information. The distinction between declarative and nondeclarative memories is highlighted by the loss of declarative memories in amnesics, with largely preserved nondeclarative memories. Also, highlighting the idea that different kinds of information in memory are processed differently, amnesias can target specific kinds of information. For example, with semantic amnesia, people lose the ability to process certain types of world knowledge. There can also be a loss of language-specific, musical, or face identification memories.

STUDY QUESTIONS

1. How is amnesia different from normal forgetting?
2. How does retrograde amnesia occur? What are some of its defining characteristics? How does this relate to Ribot's gradient?
3. What do electroconvulsive shocks do to memory? How extensive can the damage be?
4. What is anterograde amnesia? This condition is produced by damage to which brain structures?
5. What types of memories are damaged in anterograde amnesia? What types of memories are preserved? What is the general prognosis for people with this condition?
6. What is transient global amnesia? How extensive is the loss? How long does it last? Who does this happen to?
7. What are specific kinds of memory loss that can be targeted by amnesias?
8. What sorts of memory losses occur with short-term memory amnesias? How are these different losses associated with different parts of the brain?
9. What is psychogenic amnesia? What is repression? What is dissociative amnesia? What is a psychogenic fugue? What memory losses can occur in dissociative identity disorder?

KEY TERMS

- amnesia
- amusia
- anomia
- anterograde amnesia
- aphasia
- apraxia
- Broca's aphasia
- consolidation
- dissociative amnesia
- dissociative fugue
- dissociative identity disorder
- electroconvulsive shock (ECS)
- electroconvulsive therapy (ECT)
- fugue and flight
- generalized amnesia
- Korsakoff's syndrome
- localized amnesia
- memory fugue
- organic amnesia
- prosopagnosia
- psychogenic amnesia
- regression fugue
- repression
- retrograde amnesia
- Ribot's gradient
- semantic amnesia
- systematized amnesia
- transient global amnesia (TGA)
- Wernicke's aphasia

EXPLORE MORE

Here are some additional readings that can allow you to further explore issues of amnesia.

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Campbell, R. E., & Conway, M. A. (1995). *Broken Memories: Case Studies in Memory Impairment*.

Oxford: Blackwell.
Corkin, S. (2013). Permanent present tense: The unforgettable life of the amnesic patient (Vol. 1000). New York: Basic.
Parkin, A. J. (1997). *Memory and Amnesia: An Introduction*. New York: Psychology Press.
Ribot, T. A. (1882). *Diseases of Memory: An Essay in the Positive Psychology*. London: Kegan Paul and Trench.

NOTES

1 Like Ebbinghaus's (1885/1964) book, Ribot's (1882) book makes interesting reading, not only for the insights into consolidation and amnesia but also for how he struggles to bring together and interpret concepts and ideas that are taken as a matter of course today. The book is interesting not only for what he got right but also for what he got wrong.
2 For another description of profound retrograde amnesia, see Hunkin (1997), which describes a person who lost all memories before the age of 19.
3 For an account of Benjamin Franklin's work on electricity resulting in accidental amnesia and relief from depression when he and his friends were playing around with electricity, see Finger and Zaroub (2006).
4 Formerly multiple personality disorder.

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APPENDIX

Memory Methods

This appendix provides you with methods that can be used to calculate various indices of memory. This is intended to be in addition to any statistical course you may have taken. The qualities of these methods are discussed in Chapter 3, as well as other places throughout the book.

The appendix is divided into three sections. The first describes a signal detection analysis method using easy-to-calculate measures of discrimination and bias. The second is a measure of clustering that can be applied to recall data. The third is a way to use the process dissociation procedure to provide estimates of implicit and explicit memory.

SIGNAL DETECTION ANALYSIS

As described in Chapter 3, signal detection analyses can correct for guessing and tease apart the influences of discrimination and bias in people's responses. Signal detection analyses are typically applied to yes–no recognition data—that is, when people are presented with individual items and are asked to indicate whether each item is old or new. The following is a description of nonparametric measures of discrimination and bias that are relatively easy to calculate and interpret.

The measure of discrimination is *A*', which is a lot like *d*' but easier to calculate (following Donaldson, 1992, and Snodgrass & Corwin, 1988; see also Pollack, 1970). Here is the equation for calculating *A*' when the number of hits is greater than or equal to the number of false alarms:

$$A' = .5 + [(H - FA) \times (1 + H - \mathrm{FA})] / [4H \times (1 - FA)]$$

However, when the number of hits is less than the number of false alarms the following formula should be used:

$$A' = .5 - [(FA - H) \times (1 + FA - H)] / [4FA \times (1 - H)]$$

B” is a measure of bias, much like β, but, again, easier to calculate and based on the same principles as *A*’. Here is how to calculate *B*’’ following Donaldson’s (1992) correction:

$$B''_D = [(1 - H) \times (1 - FA) - HFA] / [(1 - H) \times (1 - FA) + HFA]$$

For these formulas, an *A*’ of .5 corresponds to chance discrimination (i.e., no discrimination). That is, when *A*’ values are around .5 it is unlikely that people are reliably recognizing old information and rejecting new information. An *A*’ value of 1 corresponds to perfect discrimination. That is, perfectly detecting old information in memory and rejecting new information. *A*’ values of less than .5 indicate below-chance identification. This may mean that people are using memory in a consistent and reliable way but not in the way you are hypothesizing. If *A*’ is negative, then you’ve calculated it wrong.

For the bias measure, negative *B*” values correspond to conservative responses. That is, people are being careful about what they are willing to identify as recognized. In contrast, positive *B*’’ values correspond to liberal responses. That is, people are willing to say that any given item has been encountered before and is remembered. *B*” values of zero correspond to no bias. B” values greater than 1 or less than –1 indicate that you’ve done something wrong in your calculations.

CLUSTERING

Another thing you may want to know is how information is structured or organized in memory. One way to do this is verifying if people have structured information in memory in a way that you think they will. For example, if you know that experts tend to organize information in a certain way you can assess the degree to which a given person’s own organization in memory matches the expert. This would tell you something about the level of this person’s expertise.

One measure of organization is called an ARC score, for Adjusted Ratio of Clustering (Roenker, Thompson, & Brown, 1971). ARC scores are applied to data from recall tests. Essentially, people recall a set of information that was learned earlier. Then, using a preconceived idea about how the information could be organized in memory, you assess the degree to which the organization approaches that ideal, taking chance into account. The basic formula for calculating an ARC score is as follows:

$$\text{ARC} = (R - E(R)) / (\max R - E(R))$$

In this formula, R stands for the number of observed categorical repetitions—that is, how many times during a person's recall were two items from the same predetermined category recalled together—for example, recalling two animal names one after the other. $E(R)$ is the number of categorical repetitions that would be expected by chance given the categories being tested for and how much the person actually recalled. In some sense, this is the amount of error that might be expected. This is the formula for calculating $E(R)$:

$$E(R) = \frac{\Sigma_i n^2}{N} - 1$$

Here, n refers to the number of items recalled from a given category i and N is the number of items recalled by a person.

Finally, max$R$ refers to the maximum number of repetitions possible if clustering perfectly conformed to expectations, again given the categories being tested and the amount of information actually recalled. The formula for calculating max$R$ is as follows:

$$\max R = N - k$$

Here, again, N is the number of items recalled by the person and k is the number of categories present in a person's recall. This calculation will result in a number that is something like a ratio, although not quite. Perfect clustering results in an ARC score of 1, whereas chance clustering results in a score of 0. Variations in the degree of clustering result in values between these two. It should also be noted that it is possible to get negative ARC scores. This indicates clustering below chance. If this value is a relatively large negative number, it might suggest that people have organized information in memory in some way other than the categories that you defined.

A related measure is the ARC' score (Pellegrino, 1971), which looks at sequential order across multiple recall attempts, rather than categorical groupings. Here is a simplified version for pairs of repetitions (rather than triples or larger units) and assuming unidirectional recall. The basic structure of the formula is similar to the ARC score. The formula for ARC' is as follows:

$$\text{ARC'} = \text{O}(ITR) - E(ITR) \,/\, \max(ITR) - E(ITR)$$

Here ITR refers to intertrial repetitions. $O(ITR)$ is the number of observed repetitions, which is derived by counting up the number of times a particular item follows another. For example, if people were to recall the months of the year, this would count as 1 if July followed June on trial t and $t + 1$. The formula for $E(ITR)$, the number of times a repetition would occur across trials by chance, is as follows:

$$E(ITR) = (N - 1)!(M - 3 + R) / N!$$

Here M is the number of items recall on trial t, N is the number of items recalled on trial $t + 1$, and R is number of items pairs that are recalled on trial t, but one or both of these items are not recalled on trial $t + 1$. The exclamation point is a mathematical symbol of a factorial function. Finally, the formula for max(ITR), the maximum number of intertrial repetitions that could occur, is as follows:

$$\max(ITR) = M - 3$$

PROCESS DISSOCIATION

The process dissociation procedure (Jacoby, 1991) is a simple way to separate out the influence of conscious and unconscious memory. Although this method is not completely precise and reliable in all cases, for the purposes of course work it should be just fine. Essentially, this method works by comparing people's performance in two conditions. In one condition, both conscious and unconscious processes are working in the same way. This is the *inclusion condition*. In the second, these processes would be working in opposition to one another. This is the *exclusion condition*. By looking at the difference in performance in these two conditions, one can derive estimates of how each is being affected by the manipulation of interest.

In the inclusion condition, people do some task that theoretically would involve implicit and explicit memory working together—for example, asking a person to report words, such as animal names, that had been seen earlier on a list of animal names. A person can do this task using either conscious or unconscious influences. In the inclusion condition, people can do the task using both explicit and implicit memory performance to produce words that were on the previous list. This is expressed in the following formula:

$$I = R + F - RF$$

Here, I stands for the inclusion condition, R stands for recollection, the explicit, conscious process—and F stands for familiarity—the implicit, unconscious process. So, the rate of remembering old items on the inclusion condition reflects the rate of explicitly recollecting items, plus the rate of remembering items based solely on implicit familiarity, minus the portion where these two overlap (e.g., if you recall something consciously, the additional unconscious familiarity doesn't give you any additional benefit).

In contrast, in the exclusion condition, people are asked to do something that puts implicit and explicit memory processes in opposition. For example, people might see a list of animal names at the initial part of the study. Then a person would be asked to report a list of animals as long as she did not use any from the list heard earlier. Thus, words from the previous list that are reported are almost certainly due to unconscious memory because if the person consciously remembered them, she should not report it. This is expressed in this formula:

$$E = F\,(1 - R)$$

Here, *E* stands for the exclusion condition. So the rate of remembering old items is the rate at which the implicit memory processes retrieve this information minus those that are rejected because they are also consciously remembered.

Thus, by separating out performance in the exclusion and inclusion conditions, one is left with the contribution of explicit memory. This can be expressed as:

$$R = I - E$$

What is due to implicit memory can also be estimated. The estimate for familiarity is:

$$F = E\,/\,(1 - I + E)$$

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